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To Dr. Roth with compliments
A. Sadek

Late Cretaceous and Early Tertiary Calcareous nannofossil and Planktonic foraminifera zones from Egypt

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Abstract. — The calcareous nannofossils from the Early Tertiary section at Gebel Gurnah (opposite Luxor) and the Maastrichtian to Paleocene section at Gebel Oweina (opposite Esna) in the Nile valley near Luxor, Egypt are described and extensively illustrated. In the Maastrichtian, the *Lithraphidites quadratus* and *Nephrolithus frequens* zones were found for the first time in Egypt; in the Paleogene the *Ellipsolithus macellus, Discoaster gemmeus* (?), *Heliolithus riedeli* (?), *Discoaster multiradiatus, Marthasterites contortus, Discoaster binodosus,* and *Marthasterites tribrachiatus* zones were recognised. Planktonic foraminifera zones present include *Globotruncana fornicata, G. gansseri,* and *Abathomphalus mayaroensis* in the Maastrichtian and *Globorotalia compressa - Globigerina daubjergensis, Globorotalia angulata, G. pseudomenardii, G. velascoensis, G. subbotinae, G. aragonensis* in the Paleogene.

N. frequens was recorded for the first time in this area and proves the presence of Upper Maastrichtian. The oldest Tertiary coccolith assemblage belongs to the *E. macellus* Zone (NP 4) and to the *G. compressa - G. daubjergensis* Zone of the planktonic foraminifera zonation. This indicates a considerable hiatus at the Cretaceous / Tertiary boundary with most of the Danian missing. On the correlation of species of *Neochiastozygus,* NP 4 is shown partly to be of Danian age. Another hiatus occurs between NP 4 and NP 6 to 8 or NP 9, the *D. multiradiatus* Zone, indicating most of the Middle Paleocene to be missing.

INTRODUCTION

Two objectives led to the cooperation of the four authors in this paper. One of us (KPN) works on a global study of the calcareous nannofossils at the Cretaceous/Tertiary boundary. The three others were interested in demonstrating that calcareous nannofossils could contribute to clarification of the age relationships and the geology of two classic sections in the Nile valley. These sections are readily divisible into rockstratigraphic units easily recognisable in the field, but many lithostratigraphic names were used by different workers for a particular rock unit. Different age assignments then led to controversy in the literature about correlations of the different units. This paper therefore includes a discussion of the correlation of the two sections investigated here (Gebel Gurnah and Gebel Oweina) with sections of the same age at other localities in Egypt as well as a correlation of the calcareous nannofossil assemblages to the worldwide « Standard Zonation » of Martini (1971).

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STRATIGRAPHY

Gebel Oweina Succession

Gebel Oweina (see fig. 1) is a conspicuous outlier, 450 m high and lying about 20 km SE of Esna on the eastern side of the Nile. It lies about 8.5 km to the NE of the Sibaiya station. The section was first studied by Beadnell (1905), later by Youssef (1954), Said and Sabry (1964), Krasheninnekov and Ponikarov (1964) and was reviewed by El-Naggar (1966). Gebel Oweina is considered to be the type locality of the « Esna Shales » (Beadnell, 1905; Said, 1962) and the « Esna Group » (El-Naggar, 1966, 1970). The succession includes thick shale beds, intercalated with marly and chalky beds and is capped by a hard limestone with chert concretions.

Debate among workers on the Oweina section arises from the difficulty in settling the origin of the term « Esna Shale » and the fact that time rock units do not always coincide with lithostratigraphic units. Said (1960) used the term « Esna Shale » only for the succession of « laminated green and grey shaly clays that overlie the « Chalk » und underlie the « Thebes Formation » or the « Farafra Limestone ». He also credited the term to Beadnell, who described the shales fully in 1905. El-Naggar (1966) introduced the term Esna Group and suggested the new formation and member names adopted in this pater. He credited Zittel (1883) for introducing the Esna Shale. El-Shinnawi (1972) concluded that the term Esna Shale was originally applied by Beadnell (1905) and emended by Said (1960) to define formally a formation. El-Naggar (1966, 1970) divided the shale section at Gebel Oweina into two formations : the Sharawna Shale and the overlying Oweina Shale, separated by a distinct stratigraphic breake. The Sharawna Shale overlies the Sibaiya Formation or its substitute the Duwi Formation of Youssef (1957). The Oweina Shale, in which El-Naggar included the 23 m of the « Kilabiya Chalk Member » as a middle member between two shale members, is overlain by the Gurnah calcareous shale member and the Thebes Limestone Member of the Luxor Formation (El-Naggar, 1970). The upper Oweina Shale Member of El-Naggar's is equivalent to the lower part of Said's Esna Shale (1960).

In his review of the Upper Cretaceous - Lower Tertiary stratigraphy of Southern Egypt, Issawi (1972) mentioned that he found El-Naggar's (1966) 6 m thick conglomerate bed between the Sharawna Shale and the Oweina Shale formations to be a 20 cm thin, intraformational conglomerate separating the Maestrichtian and the Danian. He followed Said (1960) in using the 22 m thick chalk unit to divide the Nile Valley section into two mapable units : the Dakhla below and the Esna above (see also fig. 4).

From our studies it is clear that a stratigraphic break occurs at the conglomerate as well as below the Kilabiya Chalk. The conglomerate separates the Maastrichtian from the Upper Danian while the other hiatus includes at least the coccolith zone NP 5 and possibly also NP 6, NP 7 and NP 8, while it cannot be detected by foraminifera.

The lithology of the section at Gebel Oweina

The section studied and illustrated in fig. 2 includes the following lithologies, from top to base :

22 m chalk; white, weathering into pale buff colours, and clayey at the base. Includes abundant planktonic foraminifera of the *Globorotalia pseudomenardi* Zone and the basal part of the *Globorotalia velascoensis* Zone. The coccolith assemblage in the upper part of the chalk belongs to NP 9 while it belongs to NP 8 with reworked NP 7 in the lowermost part of the unit.

38 m shale; light grey, ironstained, with limonitic fossils, becoming more calcareous towards the top. The *Globorotalia compressa-Globigerina daubjergensis* Zone and the *Globorotalia angulata* Zone are present in this unit which includes a coccolith assemblage of the NP 4 Zone.
2 m conglomerate; glaucotonic, yellowish grey, with a conglomeratic marly bed at the base.

48 m shale; dark grey to greyish black, locally ferruginous; the presence of the *Abathomphalus mayaroensis* Zone and the *Globotruncana gansseri* Zone was shown. The coccolith assemblage belongs to the *Nephrolithus frequens* Zone and the *Lithraphidites quadratus* Zone.

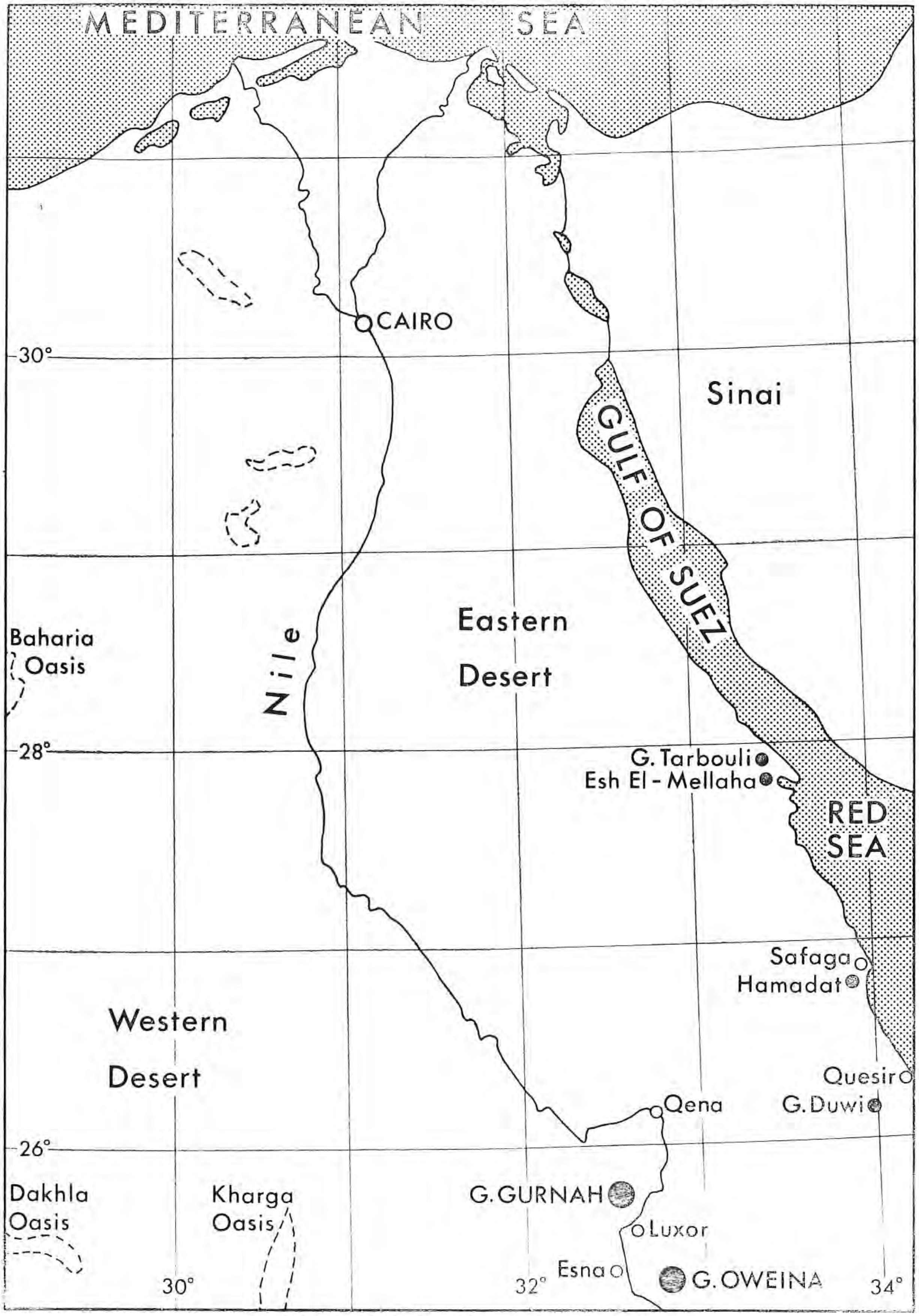

Fig. 1. Map with the localities mentioned in the text.

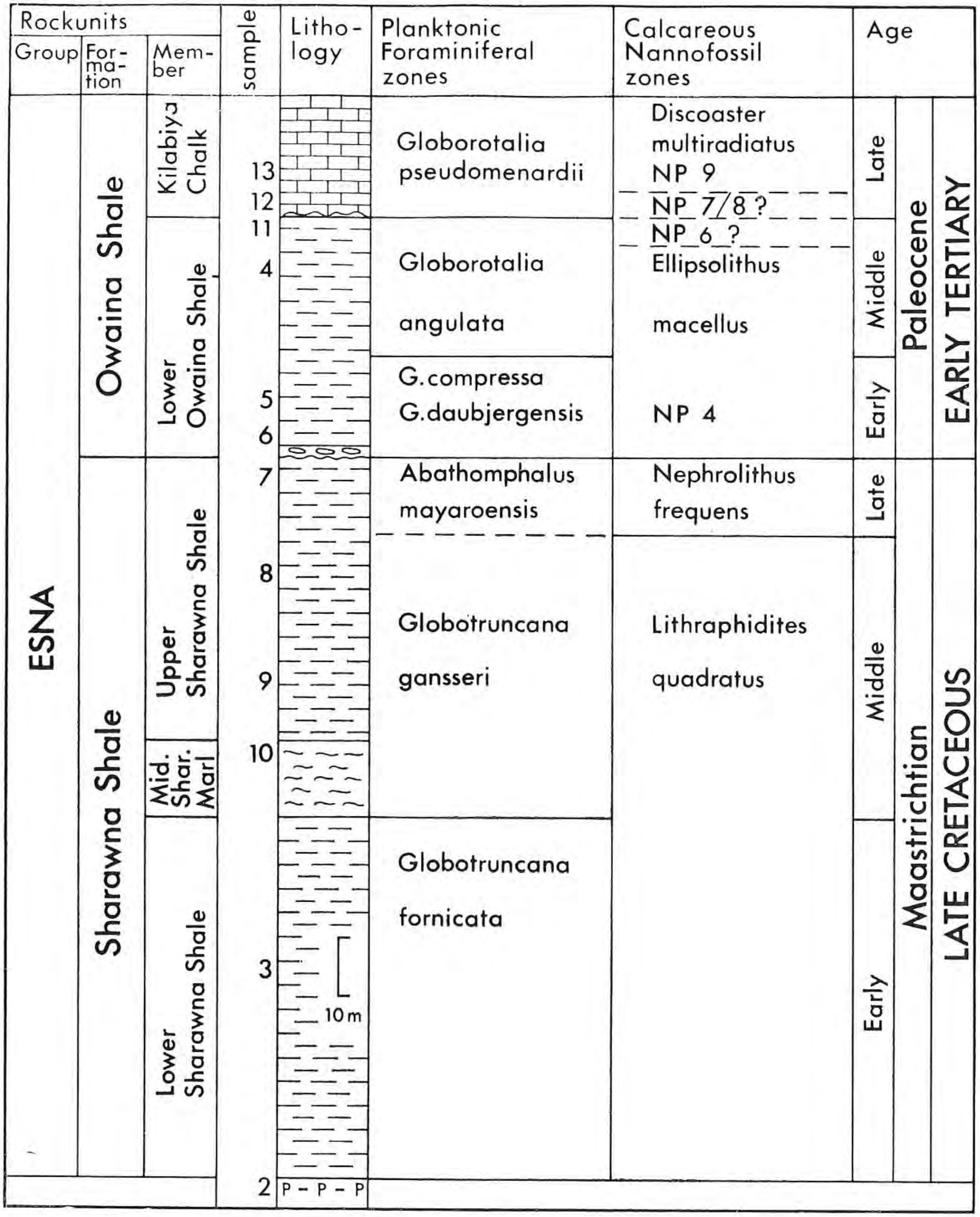

Fig. 2. Maastrichtien to Lower Eocene section at Gebel Oweina, Nile valley.

12 m marl; pale yellowish to pale grey, ferruginous marly clay, clayely marl and marls containing planktonic foraminifera belonging to the *Globotruncana gansseri* Zone and coccoliths belonging to the *L. quadratus* Zone.

57 m shale; ash-grey, ironstained, locally ferruginous, paper-like shale with thin intercalated marly bands with *Pecten* sp., intercalated with gypsum and anhydrite bands. The planktonic foraminifera belong to the *Globotruncana fornicata* Zone, the coccolith assemblage to the *Lithraphidites quadratus* Zone.

10 m Phosphate beds with very rare planktonic foraminifera in its upper parts and no coccoliths.

Gebel Gurnah Succession

Gebel Gurnah (see fig. 1) is a hill lying on the western side of the Nile, opposite Luxor. About 400 m high, it lies behind the temple of Deir El-Bahari. The famous section was, among others, studied by Delanous (1968), Zittel (1883), Cuvillier (1930), Nakkady (1951), Said (1960, 1962), Krasheninnikov and Ponikarov (1964), Berggren (1964, 1969) and El-Naggar (1966, 1970).

Gebel Gurnah is the type locality of the « Thebes Formation » of Said (1960) and its substitute, the « Luxor Formation » of El-Naggar (1970). The section includes a thick unit of limestone intercalated with flint beds and marly beds and overlying thinly bedded calcareous shales with marly bands and greenish grey shales (base not exposed).

The section at Gebel Gurnah possibly includes the Paleocene/Eocene boundary, here set between the coccolith zones NP 9 and NP 10, in the lowermost part of the outcropping layers. The coccolith assemblages of the two lowermost samples from this section (14 & 15) are very similar and both have an Eocene aspect with *Fasciculithus* and *Toweius eminens* and *T. tovae*, typical Paleocene forms, missing. However typical forms of *M. bramlettei* have not yet developed from *R. cuspis* in sample 14, while they are present in sample 15. Berggren (1964, 1969) placed the Paleocene/Eocene boundary below the outcropping section, while Said (1960) placed it at the base of the Thebes Limestone. El-Naggar (1966-1970) suggests that the section is of Early Eocene age but does not exclude the possibility that the shaly basal few meters belong to the uppermost Paleocene.

The lithology of the section at Gebel Gurnah

The section studied and illustrated in fig. 3 includes the following lithologies, from top to base :

300 m limestone with intercalating flint bands and marly beds. In the basal 2 m studied here, planktonic foraminifera of the *Globorotalia aragonensis* Zone were found together with a poorly preserved coccolith assemblage of the ? NP 12.

51 m shale; calcareous, dark grey to greenish, nearly black, thinly bedded, occasionally ferruginous, interbedded with marls.

The planktonic foraminifera found belong to the *Globorotalia subbotinae* and the *Globorotalia aragonensis* Zone while the coccoliths indicate the presence of NP 11 and NP 10.

5 + x m shale; grey to greenish, laminated, ironstained, with gypsum and anhydrite bands passing upwards into calcareous shales; the *Globorotalia velascoensis* Zone is indicated to be present by the planktonic foraminifera, while the coccoliths belong to NP 9 (see above).

BIOSTRATIGRAPHY

Two important biostratigraphic tools, the planktonic foraminifera and the calcareous nannofossils were applied in this study to subdivide the Upper Cretaceous - Lower Tertiry succession into a number of zones that can be correlated with zones elsewhere.

Calcareous Nannofossils

Recently calcareous nannofossils have attracted the attention of biostratigraphers in Egypt and several workers have published on the calcareous nannofossils of the Upper Cretaceous and/or Lower Tertiary : Sadek (1968, 1971, 1972), Kerdany (1970), Shafik (1969, Sadek and Abd El-Razik (1970), El-Dawoody and Barakat (1972), (1972), Sadek and Teleb (1973 a, b) and Shafik and Stradner (1971), the last publication including transmission electron microscope investigations.

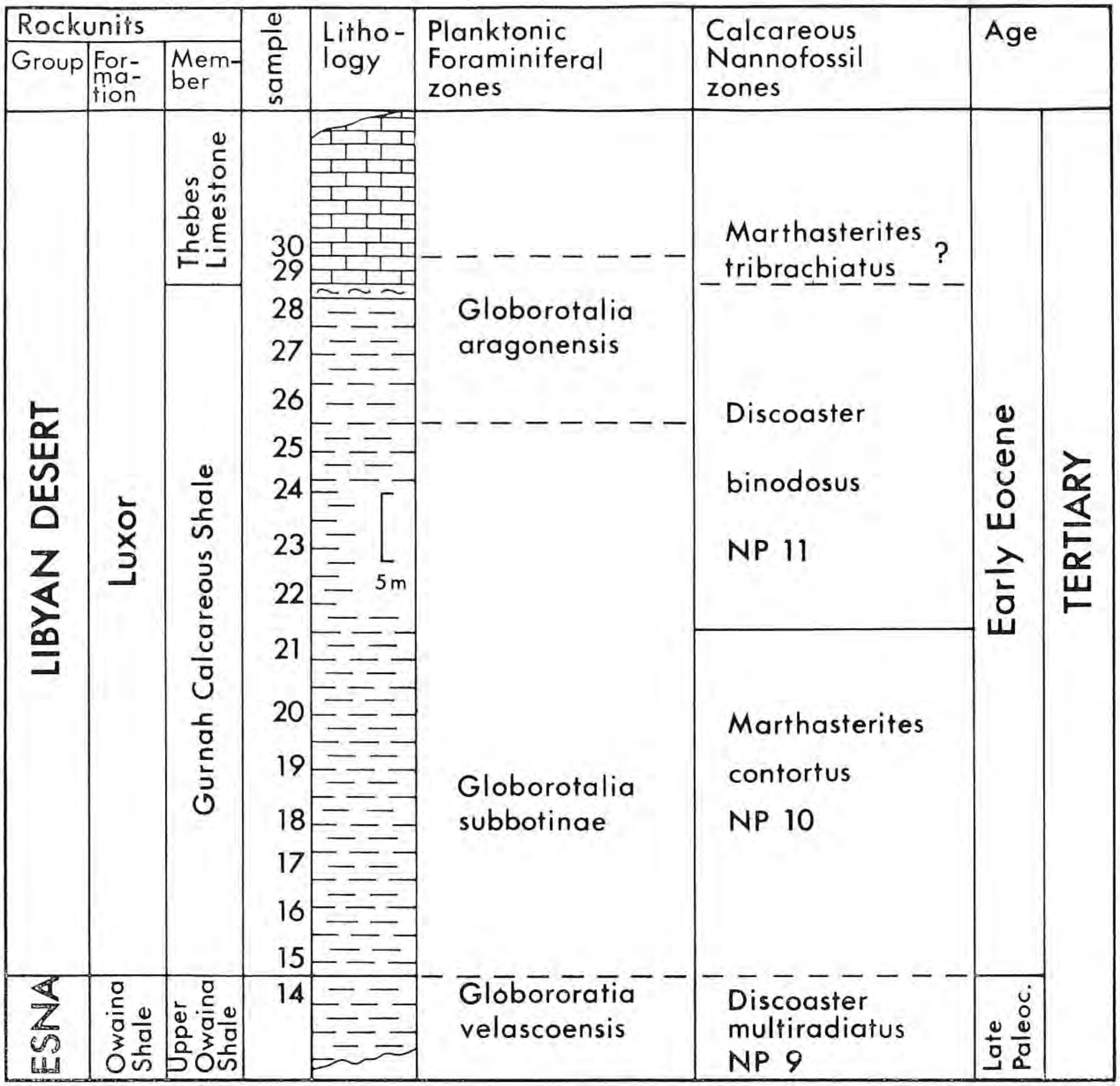

Fig. 3. Lower Tertiary section at Gebel Gurnah (Loxor).

In the last decade the Cretaceous/Tertiary boundary all over the world has attracted special attention by coccolith-specialists such as Deflandre (1959), Stradner (1963), Bramlette and Martini (1964), Perch-Nielsen (1969, 1973), Worsley (1971), Edwards (1966, 1973) and others. Coccolith zonations have been proposed for the Upper Cretaceous by different workers and a « Standard Tertiary calcareous nannoplankton zonation » was compiled by Martini (1971). In the following, we adopt these internationally well established and well defined zones and discuss, as far as possible, their occurrence in Egypt and compare it with other sections studied in Egypt and abroad.

Upper Cretaceous (Maastrichtian)

1) *Lithraphidites quadratus* Zone

The *L. quadratus* Zone spans the interval from the first occurrence of *L. quadratus* to the first occurrence of *Nephrolithus frequens*. This definition of the zone was given by Cepek & Hay in 1969. The *L. quadratus* Zone is not present in the lowermost Maastrichtian of the type area and thus indicates a somewhat higher stratigraphical position in the Maastrichtian. The zone was found in most of the Sharawna Shale at Gebel Oweina. It is also reported from the Tarbouli section, Gulf of Suez, where it represents the youngest Maastrichtian present (Shafik &Stradner, 1971). For species distribution see table I.

2) *Nephrolithus frequens* Zone

The *N. frequens* Zone spans the interval from the first occurrence of *N. frequens* to the level of extinction of most Cretaceous species at the Cretaceous/Tertiary boundary (Cepek & Hay, 1969). The Upper Maastrichtian of the type region belongs to the *N. frequens* Zone. This is the first report of the occurrence of *N. frequens* in Egypt and at a low geographical latitude. The species has been shown to occur mainly in high latitudes Upper Maastrichtian by Martini & Worsley (1971). The presence of *N. frequens* in one sample only in the section at Gebel Oweina suggests the Upper Maastrichtian to be present but reduced in thickness by non-deposition or erosion. This is further marked by the absence of *Tetralithus murus,* a species known to be present in the Upper Maastrichtian of tropical seas and occuring only little later than *N. frequens* in sections where they occur together, as in southern France. For species distribution see table I.

Paleocene

Markalius inversus Zone (NP 1) to *Chiasmolithus danicus* Zone (NP 3)

None of these coccolith zones were found to occur in the sections studied here. NP 1 was, however, reported possibly to be present in the Gebel Abu Had section at the mouth of Wadi Quena (Kerdany, 1970). NP 2, the *Cruciplacolithus tenuis* Zone has so far not been found in Egypt. Where the *C. tenuis* Zone was mentioned to occur, it was understood in the sence of Hay and Mohler (1967), where it included the later described NP 2, NP 3 and NP 4 (i.e. in Kerdany, 1970). The presence of the *Chiasmolithus danicus* Zone (NP 3) is probable in one or several of the localities studied by Kerdany (1970). But as he gives no detailed species lists for each locality, its presence cannot be verified.

3) *Ellipsolithus macellus* Zone (NP 4)

The oldest Tertiary coccolith assemblage found in the Gebel Oweina section belongs to the *E. macellus* Zone of Late Danian age. It includes the interval from the first occurrence of *E. macellus* to the first occurrence of *F. tympaniformis.* Although Kerdany (1970) did not mention *E. macellus* in his species list, the presence of the *E. macellus* Zone in one or several of his localities is probable. He lists the first occurrence of « *Heliorthus concinnus* » which, in the large sense he probably uses it, has its first occurrence in the upper part of the *E. macellus* Zone according to Martini (1971), below the first occurrence of *F. tympaniformis.* For species distribution see tables II and III.

4) *Fasciculithus tympaniformis* Zone (NP 5)

No assemblages belonging to this zone were found in the Gebel Oweina section. Kerdany (1970), although he states that the absence of the *F. tympaniformis* Zone from his scheme did not imply a hiatus but was due to his definition of the underlying and overlying zones, indicates that *F. tympaniformis, H. kleinpelli* and *H. riedeli* have a common first appearance at the base of his *H. kleinpelli* Zone. This suggests that there actually is a hiatus in his sections, too, as in the section at Gebel Oweina. The common first occurrence of *F. tympaniformis* and *H. kleinpelli* is probably due to reworking of older assemblages into the *H. kleinpelli* Zone (NP 6), while the *H. riedeli* recorded there might be *H. conicus,* a newer species similar to *H. riedeli,* but which occurs earlier. This is indcated by the absence of discoasters in the same assemblage, where they should occur, were it the *H. riedeli* Zone (NP 8) of Martini (1971).

5) *Heliolithus kleinpelli* Zone (NP 6)

No assemblage certainly belonging to this zone was found in the Gebel Oweina section. The zone might, however, be present in some sections described by Kerdany (1970) (see discussion of NP 5).

6) *Discoaster gemmeus* Zone (NP 7)

The presence of this zone cannot be excluded but cannot be ascertained either. The zone is defined by Martini (1971) as the interval from the first occurrence of

Calcareous nannofossil zone		L.quadratus				N.f.
Species / Sample	2	3	10	9	8	7
Ahmuellerella octoradiata	no coccoliths	R	R	R	R	R
Arkhangelskiella cymbiformis		C	C	R	R	F
Biscutum constans		R		R	R	F
Chiastozygus amphipons		R	R	R		
Chiastozygus litterarius		R	R	R	R	R
Corollithion exiguum			R			
Corollithion? madagaskarensis		R	F	R	R	R
Corollithion sp.						R
Cretarhabdus decorus		R	R	R	R	R
Cretarhabdus granulatus		R	R	R	R	R
Cribrosphaerella ehrenbergi		F	R	F	F	R
Cylindralithus oweinae		F	R	R		R
Discorhabdus ignotus		R	R	R		
Eiffelithus parallelus		R	R	R		
Eiffelithus regularis		R	F	F	R	R
Eiffelithus turriseiffeli		R	R	R	R	R
Glaukolithus cf. G.diplogrammus		F	R	R	R	R
Glaukolithus sp.1		R	R			
Heterorhabdus sinuosus		R	R	R	R	R
Holococcolith ?		R		R		R
Kamptnerius magnificus (?)						R
Kamptnerius percivallii		R	R	R	F	F
Lithraphidites carniolensis		F		R	F	R
Lithraphidites grossopectinatus			R			
Lithraphidites quadratus		F	F	F	F	C
Markalius perforatus						R
Markalius sp.						R
Micula staurophora		A	C	A	C	A
Nephrolithus frequens						F
Parhabdolithus angustus		R		R		R
Parhabdolithus splendens		R		R		
Pontosphaera multicarinata						R
Prediscosphaera bukryi						R
Prediscosphaera cretacea		C	C	C	F	C
Prediscosphaera honjoi		F	R			R
Prediscosphaera microrhabdulina		R				
Prediscosphaera rhombica		R				R
Prediscosphaera spinosa			R			
Prediscosphaera stoveri		F	R	F	R	
Pseudomicula quadrata						R
Reinhardtites mirabilis		F	F	F	F	F
Staurolithites bochotnicae		R	R	R	R	R
Staurolithites sp.1		R				R
Staurolithites sp.2		R	F	F	F	R
Stephanolithion munitum		R		R		R
Stradneria crenulata		R	R	R	R	R
Stradneria limbicrassa		R	R			R
Tetralithus aculeus		R	R			
Thoracosphaera sp.		R	R	R	F	R
Tranolithus? sp.1		R				R
Watznaueria barnesae		C	C	C	F	C
Watznaueria biporta						R
Watznaueria sp.1		R	R		R	R
Zygodiscus? pseudanthophorus		R	R	R	R	
Zygodiscus sigmoides						R
Zygodiscus spiralis		F	R	F	R	R
Zygolithus tarboulensis		R	R	R	R	R
Gen. et Sp. indet.		R		R		

Table 1. — Calcareous nannofossils in the Upper Maastrichtian at Gebel Oweina, Egypt. R : rare, F : few, C : common, A : abundant occurrence. N.f. : Nephrolithus frequens.

LOCALITY	G. OWEINA						GEBEL GURNAH																		
SAMPLES / TAXA	6	5	4	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	27	27	28	29	30	Pl. : Figs	FAMILY
Braarudosphaera bigelowi	F		R											R			R		R	F		R	R		BRAAR.
Micrantholithus flos																				R				9:44,45	
Micrantholithus sp.	R																			R				9:41,42	
Scapholithus fossilis																		R			F	R	R	23:12	CAL.
S.rhombiliformis						R																		23:11	
Lanternithus duocavus		R																							CALYPTROSPH.
Polycladolithus? sp																					R			9:56,57	
Semihololithus?cf.S.kerabyi														F	F		R				?	R		10:3-6	
Semihololithus?sp.															?				F	R	R	F	R	10:12-17	
Zygrhablithus bijugatus															R	R	F	R	F	R	R	R	R	10:7-11	
Zygrhablithus? sp.									R					R			R			R				10:1,2	
Campylosphaera dela																		R	R	F	R	R	F	12:5	COCCOLITHACEAE
C.eodela		?					R		F				R	R										8:61,62	
Chiasmolithus bidens				R																				8:77,78	
C.californicus																							R		
C.consuetus	R	R		R	R	R	F		F				R	R				R	R	R	R	R	R	8:79,80	
C.danicus				R																				11:10	
C.eograndis						?															R	R	R	8:69,70	
C.nitidus				F	R	F	R		F			R	R	R	R	R		R	R	R	R	R	R	8:75,76	
C.solitus									R				R									R	R	8:81,82	
Chiasmolithus sp.1						R			R					R				R	R	R		R	R	8:65,66	
Chiasmolithus sp.2		R																						8:67,68	
Cruciplacolithus notus	F	C	F	F	R	R																		8:83,84	
C.staurion .															R	R				R					
C.subrotundus	R	R																						8:63,64	
C.tenuis	R	R																							
Cyclococcolithina gammation																		C	F	F	F	F	F	8:39,40	
C.robusta	F	F	C	F		F																	F	8:41,42	
Cyclococcolithina sp.1	R	R	R	R		F																		8:57,58	
Ericsonia ovalis	C	C	C	C	C	C	C	R	C	R	R	F	C	C	C	F	C	C	C	C	F	C	C	12:10	
E.subpertusa	C	C	C	C	F	C	F							R									R	8:71,72	
Ericsonia sp.(E.obruta-type)									R									R			R	R			
Markalius variabilis inversus				R		F														R	R	R	R	8:36,37	
Discoaster barbadiensis																			R		R				DISCOASTERACEAE
D.cf. D.bifax							R					R												9:46,47	
D.binodosus							F	R	F	R		R	F	R	R	R	R	R		R	R	R	F	9:51	
D.diastypus							R		R			F	F	F						R	R		R	13:3	
D.distinctus																				R	R				
D.falcatus												F				R		R			R		R		
D.gemmeus				R	F																			9:43	
D.kuepperi																		?	F	?	R	R	R		
D.lodoensis																						?	?		
D.mediosus														R	R	R		R							
D.multiradiatus				?	?	R	R	R	R	R		R	R			R	R			F			F	9:49,50	
D.salisburgensis							R					R		R	R									9:48	
Discoasteroides bramlettei				R		R																		14:9	
Marthasterites bramlettei							?	R	R	R		F	F											9:52,53	
M.contortus													?	F										9:54,55	
M.tribrachiatus							F								R	R	R		R	R	R	R	R	22:1	
Rhomboaster cuspis																									
Bomolithus elegans				R	F	F																		9:25,26	FASCICUL.&HELIOL.
Fasciculithus billii						R																		9:19,20	
F.bobii						F																		9:21,22	
F.involutus				F	R	F																		9:17,18	
F.tympaniformis				C	F	C																		9:15,16	
Fasciculithus sp.1				F		F																		9:36-38	
Fasciculithus sp.2				R		R																		9:31	
Heliolithus? cantabriae						R																		9:9,10	
H.kleinpelli				?		F																		9:11-14	
CALCAREOUS NANNOFOSSIL ZONES NP		4	?	6	–	9	9?	–		10							11					?	12		

Table II. — Calcareous nannofossils in the Paleogene at Gebel Oweina and Gebel Gurnah, Egypt. Symbols see table I.

G.OWEINA						GEBEL GURNAH																	LOCALITY	Pl. Figs	FAMILY
6	5	4	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	SAMPLES / TAXA		
												R					R	R	F	R	R	R	Discolithina pectinata	10:51,52	PONTOSPH.
					F																		Pontosphaera rimosa	10:55,56	
						R						R					R	R	R	R		R	P.versa	10:59,60	
						F		R							R				R	R	R	k	Transversopontis cf.T.exilis	10:61,62	
						R		R			R	R	R	R	F	F	F	F	R	R	R	R	T.cf.T.rectipons	10:53,54	
													R				R	R	R	R	R	R	Transversopontis sp.1	10:49,50	
			F	F	F																		Prinsius bisulcus		PRINSIACEAE
F	C																						P.dimorphosus		
C	C	R	C	F	F																		P.martinii	18:4	
						C	R	C	R	R	C	C	F	F	R	R	F	F	F	F	F	C	Toweius callosus	18:5,8	
			F	F	C	C	R	F	R	R	C	C	F	F	R	R	R	F	F	F	F	C	T.craticulus s.l.	18:12	
			F	F	C												r	r	r				T.eminens	18:6,7	
					R																		T.occultatus	18:3	
F	F	R	R	F	C	R	R	F	R	R	F	C	F	F	F	R	C	F	R	R	R	F	T.rotundus	18:15	
			F	F	F																		T.tovae	18:11	
												F	F	F	F	R	F	F	F	F	F	F	Toweius? sp. (large)		
												R											Blackites spinosus	23:17	RHABD.
						R		R				R	R				R	R	R	F	R	R	Rhabdolithus solus	8:53,54	
																				R			Rhabdosphaera cf.R.truncata	8:51,52	
					R																		Sphenolithus anarrhopus	8:48-50	SPHENOLITHACEAE
												R		F		R		R	R	R	R		S.editus, large	8:22-24	
												R	F	F	R	F	F						S.editus, intermediate	8:43-45	
													R					F				R	S.editus, small	8:25-27	
			F	F	C	F		F			R	R											S.primus, large	20:3	
													F	F	F	R					R		S.primus, small	8:46,47	
																		R	R	R	R	F	S.radians	8:6-8	
														R		R	R	R	R		R		Sphenolithus sp.1	8:1-3	
	F	R			R	R		R			R												Ellipsolithus distichus s.l.	10:69,73	SYR.?
				R				R			R	R	R			R	R		F	F	R	R	E.macellus, large	10:75,76	
R	R		R																				E. macellus, small	10:71,72	
C	C	C	C	C	F	F		R			R	F	F	R	F	F	F	F	F	F	F	F	Thoracosphaera operculata & sp.	9:29,30	T.
																					R		Chiphragmalithus calathus	10:45-48	ZYGODISCACEAE
					R																		Neochiastozygus chiastus	10:41,42	
			F	F	F														R				N.cf.N.denticulatus	10:34,35	
F	R																						N.distentus	10:24,25	
						R																	N.distentus	10:26,27	
			R		R	R																	N.distentus	10:30,31	
						R		F			R		R	R				R	R		R	R	N.distentus	10:32,33	
						F		C			F	F	F	F	R	R							N.junctus	10:28,29	
					R			?															N.perfectus	10:43,44	
?R	R																						N.saepes	10:20,21	
F	F	F	R																				Neochiastozygus sp.1	10:22,23	
R	F																						Neochiastozygus sp.2	10:37,38	
													R	R	R			R	R	F	R	R	Neococcolithes cf.N.dubius	10:36	
			R																				N.protenus	21:10	
								R										R	R	R	R		Lophodolithus nascens	10:67,68	
						R		R															Lophodolithus? sp.	10:63,64	
								R															Zygodiscus adamas	19:5	
				?				R				R		R	R	R				R	R		Z. plectopons	10:65,66	
C	F	R	R	R	F			?															Z.sigmoides	19:1-3	
						?		R															Zygodiscus? sp.	10:57,58	
					R	R																	Hornibrookina australis	10:57,58	?
4			?6		9	9?	10					11									12?		CALCAREOUS NANNOFOSSIL ZONES NP		
PALEOCENE						EARLY EOCENE																	AGE		

Table III. — Calcareous nannofossils in the Paleogene at Gebel Oweina and Gebel Gurnah, Egypt. Symbols see table I.

D. gemmeus to the first occurrence of *H. reideli*. *D. gemmeus* is present in samples 11 and 12 at the Gebel Oweina section, but also present are *Heliolithus* sp. and *Discoaster* cf. *D. multiradiatus,* both too poorly preserved to be determinable with certainity. The zone might be present in sections studied by Kerdany (1970), although he did not distinguish it and did not tabulate or mention *D. gemmeus.*

7) *Heliolithus riedeli* Zone (NP 8)

The same remarks on the presence of the *H. riedeli* Zone at Gebel Oweina have to be made as for the *D. gemmeus* Zone. The one sample, where it might be present, has too poorly preserved coccoliths to allow its recognition. As to its presence in sections treated by Kerdany (1970), we cannot judge from his publication, whether the zone in Martini's (1971) definition is represented or not.

Shafik & Stradner (1971) found the *H. riedeli* Zone to be well developed in the Tarawan Chalk of the Gebel Duwi succession, but absent in the Gebel Tarbouli section.

8) *Discoaster multiradiatus* Zone (NP 9)

This zone is defined by Martini (1971) to include the interval from the first occurrence of *D. multiradiatus* to the first occurrence of *Marthasterites bramlettei.* It was found to be present in the Kilabiya Chalk at Gebel Oweina and possibly at the base of the outcropping section at Gebel Gurnah. At Gebel Oweina, the very rich assemblage (see tables II and III) includes probably reworked specimens of *H. kleinpelli,* which seems to have its last occurrence in NP 7 (Martini, 1971).

The *D. multiradiatus* Zone in this definition has been recognised by Sadek & Abd El-Razik (1970) at the Red Sea coast, by Kerdany (1970) at localities he studied and by Sadek (1971) from different but not specified localities.

Shafik & Stradner (1971) used a somewhat different definition of the zone by taking its upper boundary at the first occurrence of *Marthasterites spineus* which they found below the first occurrence of *M. bramlettei*. The upper part of the *D. multiradiatus* Zone as defined here was called *Marthasterites spineus* Zone. The latter was found to occur in the Esna Shale of the wadi Had section south of Gebel Duwi and in the same formation of the Esh- El-Mellaha range sediments. It was not detected neither in the Gebel Tarbouli section, nor in the sections studied by us. The *D. multiradiatus* Zone is the uppermost Paleocene unit. For species distribution see tables II and III.

Early Eocene

9) *Marthasterites contortus* Zone (NP 10)

This zone includes the interval from the first occurrence of *Marthasterites bramlettei* to the last occurrence of *M. contortus*. It is well developed in the Gurnah Calcareous Shale in the Gebel Gurnah section. The change in assemblage from the *D. multiradiatus* Zone to the *M. contortus* Zone is considerable, a fact reported from sections all over the world, where a succession is found that includes the Paleocene/Eocene boundary. The boundary is set between the two zones. For comparison of the different assemblages compare tables II and III.

Kerdany (1970) used a slightly different definition of the *M. contortus* Zone than the one used here, in that he considered the upper boundary at the first occurrence of *M. tribrachiatus*. This does make the zone a little shorter only. He recognized it in the Gebel Gurnah section. Sadek and Abd El-Razik (1970) recorded the *M. bramlettei* Zone from Gebel Um El-Huetat at the Red Sea coast. Sadek (1971) introduced the « *M. contortus* - *M. bramlettei* Zone for the interval of the *M. contortus* Zone. Also El-Dawoody and Barakat (1972) recognised the *M. contortus* Zone in the Gebel Duwi section, where it was also found by Shafik and Stradner (1971). The latter authors found it, too, at Gebel Hamraween, at Hamadat section and on Gebel Tarbouli.

10) *Discoaster binodosus* Zone (NP 11)

This zone is defined to include the interval from the last occurrence of *M. contortus* to the first occurrence of *Discoaster lodoensis*. Where *M. contortus* is absent, *M. tribrachiatus* is often used as the marker for the lower boundary of this zone. The *D. binodosus* Zone is well developed in the Gebel Gurnah section.

Kerdany (1970) reported this zone, with *M. tribrachiatus* as the base, in his study and also noted, that its uppermost part falls within the finely crystalline limestone of the Thebes Formation, in which he found no calcareous nannofossils. Shafik & Stradner (1971) found the *D. binodosus* Zone in the upper half of the Esna Shale at Gebel Tarbouli and in the uppermost part of the same formation of the Hamraween section and the Gebel Duwi section. It was also found at the latter locality by El-Dawoody & Barakat (1972), who, however, used a different definition of the zone. For species distribution see tables II and III.

11) *Marthasterites tribrachiatus* Zone (NP 12)

This zone is defined to include the interval from the first occurrence of *D. lodoensis* to the last occurrence of *M. tribachiatus*. Its presence in the section at Gebel Gurnah is not certain, as no typical, well preserved *D. lodoensis* were found in the largely recrystallised limestone of the Thebes Formation.

Sadek & Abd El-Razik (1970) recognized the *M. tribrachiatus* Zone at Gebel Um El Huetat at the Red Sea coast. They also noted that the *M. tribrachiatus* Zone is represented extensively in Esh El-Mellaha, Gebel Duwi, Gebel Oweina, Gebel Senai and Gebel Abu Had. El-Dawoody and Barakat (1972) as well as Sadek (1971, 1972) recorded a zone of *M. tribrachiatus* but state that they did not find *D. lodoensis* in the assemblage. Following the definition used here, it is not NP 12 but belongs into NP 11. *D. lodoensis* is, however, reported to occur in younger deposits, without *M. tribrachiatus* but with *D. sublodoensis* in the Burg El-Arab well, western Desert (Sadek, 1972).

No younger Eocene zones were investigated in the present study, but several were recorded by Sadek (1972) and Sadek and Teleb (in print) to occur in Egypt.

Planktonic Foraminifera

The planktonic foraminifera of the Upper Cretaceous-Lower Tertiary strata of the areas under consideration have been dealt with by Nakkady (1951, 1957, 1958), Said (1960), Said and Sabry (1964), Krasheninnikov and Ponikarov (1964), El-Naggar (1966) and others.

In the present study, nine foraminiferal zones could be recognised by the detailed examination of the encountered fauna.

Upper Cretaceous (Maastrichtian)

1) Interval with very rare planktonic foraminifera

The samples studied from the phosphatic beds below the Lower Sharawna Shale in the Gebel Oweina section yielded no identifiable planktonic foraminifera. According to Said (1962) the phosphorite beds are Maastrichtian in age, while El-Naggar (1966) suggests a Late Campanian age for them and Krasheninnikov and Ponikarov (1964) assigned them to the Campanian-Maastrichtian boundary. The phosphatic beds at Gebel Oweina can be correlated with similar phosphatic deposits in Quseir, Safaga, Dakhla and Kharga (see fig. 1). The age of these layers in Quseir is Campanian in its lower part and Maastrichtian in its upper part (Youssef, 1957); it is Early Maastrichtian in Safaga (Faris and Hassan, 1959), Dakhla (Said, 1961) and Kharga (Nakkady, 1959). In this study, the age of the uppermost phosphatic beds is Early Maastrichtian.

2) *Globotruncana fornicata* Zone

Our concept of this zone is similar to that of El-Naggar (1966) and the zone is defined by the occurrence of *G. fornicata* Plummer together with *G. arca* (Cushman), *G. stuarti* (De Lapparent), *G. conica* White and *G. lamellosa* Sigal. In addition occur *G. aegyptiaca aegyptiaca* Nakkady, *G. gagnebini* Tilev, *G. ventricosa* White, *G. leupoldi* Bolli and *Hedbergella* sp.

The zone was found in the Lower Sharawna Shale at Gebel Oweina and dates it to Early Maastrichtian.

3) *Globotruncana gansseri* Zone

This zone is characterised by the common occurrence of *G. gansseri* Bolli and the absence of *Abathomphalus mayaroensis* Bolli of the overlying zone. *G. gansseri, G. contusa* (Cushman) and *Rugoglobigerina rotunda* Bronnimann make their first appearance at the base of the zone. *G. esnehensis* Nakkady & Osman, *G. aegyptiaca aegyptiaca, G. arca* (Cushman), *G. stuarti* (De Lapparent) and *G. conica* also occur.

The zone was found in the Middle Sharawna Marl and in the lower part of the Upper Sharawna Shale at Gebel Oweina and dates these sediments as Middle Maastrichtian.

4) *Abathomphalus mayaroensis* Zone

Our concept of this Zone is similar to that of Beckmann et *al.* (1969). The zone is characterised by the presence of *A. mayaroensis* which is restricted to the uppermost Upper Sharawna Shale at Gebel Oweina and dates it to Late Maastrichtian. Other planktonic foraminifera include *G. contusa, G. esnehensis,* and *G. stuarti.* The lower boundary of the zone is marked by the disappearance of *G. arca* and *G. gansseri.* The top of the zone is marked by a distinct change in the assemblage of planktonic foraminifera. In the section at Gebel Oweina studied here, it coincides with a break in sedimentation and / or erosion before the deposition of the Upper Danian layers. El Naggar (1966) noted that *G. esnehensis* is more abundant than. *A. mayaroensis* and named the zone after the more common species.

Lower Paleocene (Danian)

5) *Globorotalia compressa / Globigerina daubjergensis* Zone

This zone is characterised by the complete absence of the Upper Cretaceous forms of *Globotruncana, Rugoglobigerina, Hedbergella* and *Abathomphalus* and by the first appearance of lower Tertiary planktonic foraminifera of the *Globigerina* and *Globorotalia* assemblage. Apart from the two index fossils which are restricted to the zone, *Globigerina pseudobulloides* Plummer, *G. trinidadensis* (Bolli) and *G. triloculinoides* Plummer appear for the first time.

The zone, of Late Danian age, was found in the Lower Oweina Shale that unconformably overlies the Late Maastrichtian Upper Sharawna Shale at Gebel Oweina. A disconformity and a well developed conglomerate with reworked Maastrichtian and a Danian fauna mark the base of this zone according to El-Naggar (1966). The latter and Krasheninnikov and Ponikarov (1964) already noted the absence of Lower Danian planktonic foraminifera in the Gebel Oweina section. Our studies, too, show that the Lower and Middle Danian is missing in this section. The Upper Danian is thin and *Globorotalia compressa* (Plummer) is common throughout it.

Middle Paleocene (Montian, Heersian)

6) *Globorotalia angulata* Zone

This zone is characterised by the presence of angulo - conical *Globorotalia* species, examplified by *G. angulata* (White). This makes the *G. angulata* Zone easily identifiable and differentiable from the Upper Danian. Its upper boundary is marked by the first occurrence of the sharply keeled *Globorotalia* such as *G. pseudomenardii* Bolli and *G. velascoensis* (Cushman) found in the overlying Upper Paleocene. The lower boundary is marked by the first appearance of *G. angulata, G. angulata abundocamerata* Bolli, *G. ehrenbergi* Bolli and *G. pusilla pusilla* Bolli. Other forms found in this zone include *G. uncinata uncinata* Bolli, *G. perclara* Loeblich & Tappan, *G. pseudobulloides* (Plummer), *G. quadrata* (White), *Globigerina triloculinoides* Plummer, *G. spiralis* Bolli, *G. kozlowskii* Brotzen & Pozaryska and *G. inaequispira* Subbotina.

This zone is equated with most of the *Globorotalia uncinata* and the *Globorotalia pusilla* zones of Bolli (1957). These two zones were considered as subzones of the *G. angulata* Zone by El-Naggar (1966). It also corresponds to the *G. angulata* zone and the upper part of the underlying « *Acarinina uncinata* » zone of Krasheninnikov & Ponikarov (1964).

The *G. angulata* Zone occurs in the upper part of the Lower Oweina Shale at Gebel Oweina.

Upper Paleocene (Landenian)

7) *Globorotalia pseudomenardii* Zone

This zone is characterised by *G. pseudomenardii* which is restricted to it. This concept corresponds to that of Bolli (1957) and of Beckman et *al.* (1969) The lower limit is also marked by the first appearance of *Globorotalia velascoensis velascoensis* (Cushman). El-Naggar (1966) noted that the first occurrence of *G. velascoensis velascoensis* does not coincide with the base of the Kilabiya Chalk but occurs slightly below it in a calcareous shale in the section at Gebel Oweina, where the *G. pseudomenardii* Zone is the youngest zone represented.

8) *Globorotalia velascoensis* Zone

This zone is characterised by the presence of *G. velascoensis velascoensis* and the absence of *G. pseudomenardii*. The assemblage includes also *G. velascoensis parva* Rey, *G. aequa* Cushman & Renz, *G. acuta* Toulmin, *Globigerina primitiva* (Finlay), *G. soldadoensis* Brönnimann, *G. inaequispira, G. mackannai* White and *Globorotalia esnaensis* (Le Roy).

A Late Paleocene age may be assigned to this zone which was found at Gebel Gurnah from the coccolith assemblage found in the same sample and probably belonging to NP 9 of the uppermost Paleocene. Said (1960) assigned the whole shaly part of the section at Gebel Gurnah to the Paleocene while El-Naggar (1966) gave an Early Eocene age to the shales and the limestones. He mentioned, however, the possibility of a Late Paleocene age for the lowermost few meters of shales, and later (1970) excluded the Eocene part of the sequence from the Esna Group and renamed it « Gurnah Calcareous Shale Member ».

Lower Eocene (Ypresian)

a) *Globorotalia subbotinae* Zone

This zone is characterised by the presence of *G. subbotinae,* the absence of *G. velascoensis* and the last occurrence of *G. aequa. Pseudohastigerina wilcoxensis* (Cushman and Poncton) and *Globorotalia formosa gracilis* Bolli have their first occurrence here. The assemblage includes also *G. marginodentata* Subbotina, *G. formosa formosa* Bolli, *G. pseudotopilensis* (Subbotina), *G. lensiformis* Subbotina, *G. esnaensis, Globigerina collactea* (Finlay), *G. gravelli* Brönnimann, *G. linaperta* Finlay and *G. primitiva* (Finlay).

The presence of this zone indicates an Early Eocene age for the lower part of the Gurnah Calcareous Shale at Gebel Gurnah.

10) *Globorotalia aragonensis* Zone

This zone is characterised by the common occurrence of the following species : *Globorotalia aragonensis* Nuttal, *Globigerina prolata* Bolli, *G. soldadoensis* Brönnimann and *Acarinina interposita* Subbotina. Other species found were *Pseudohastigerina wilcoxensis* (Cushman & Ponton), *Globorotalia braodermanni* Cushman & Bermudez, *G. aspensis* (Colom), *Globigerina collectea* and *G. linaperta*. Its lower boundary is marked by the disappearance of *Globorotalia subbotinae, G. formosa gracilis* and *Globorotalia wilcoxensis*.

The zone occurs in the upper part of the Gurnah Calcareous Shale and in the lowermost part of the Thebes Limestone which it dates as late Early Eocene in the section at Gebel Gurnah. It is the youngest zone studied in this investigation.

REMARKS ON CALCAREOUS NANNOFOSSILS

The following remarks on the calcareous nannofossils include the description of a new genus and four new species and some comments on the occurrence of selected families, genera and species. No lists of synonymies are given for the species used in this study, since most species are illustrated here.

Cretaceous

The Maastrichtian assemblages are reasonably well preserved and more diverse than previously found (Perch-Nielsen, 1973). They are usually dominated by *Micula staurophora* with *Prediscosphaera cretacea, Watznaueria barnesae* and, in the lowermost two samples, *Arkangelskiella cymbiformis* as common species. Of special interest is the presence of *Nephrolithus frequens* in the uppermost Maastrichtian sample. It indicates a Late Maastrichtian age for the top of the Cretaceous sequence.

Pseudomicula Perch-Nielsen n. gen.

Generotype : *Pseudomicula quadrata* Perch Nielsen n. sp.

Diagnosis : Nannolith with a quadratic outline, built up by (8?) more or less pyramid-shaped bodies, where the top of the pyramid is oriented towards the center of the nannolith.

Pseudomicula quadrata Perch-Nielsen n.sp.

Pl. 1, figs. 43, 44; Pl. 7, figs. 3, 6, 9

Holotype : Pl. 7, figs 6, 9 (turned specimen);

Type level : Late Maastrichtian, *N. frequens* Zone.

Type locality : Gebel Oweina, sample 7; Egypt.

Diagnosis : Nannolith built up by 8 (?) more or less pyramid-shaped bodies. The top of the pyramid points towards the center of the nannolith.

Description : The outline of this nannolith is nearly quadratic. The base of the hollow, pyramid-shaped bodies is a parallelogram rather than quadratic.

Remarks : On first sight, this species resembles *Micula staurophora* from which it is distinguished by the form of the bodies building up the nannolith.

Occurrence : *P. quadrata* is rare in the Late Maastrichtian sample from Gebel Oweina and was not found in any other sample.

Tertiary

The abundance and the preservation of the calcareous nannofossils in the Tertiary samples differ considerably. Solution and/or overgrowth have affected the coccoliths and nannoliths in most samples. In some, only a very poorly preserved and little diverse assemblage is left while in others, the assemblage is still quite divers, but owergrowth has affected specially discoasters and sphenoliths so much, that their identification is almost impossible.

Braarudosphaeraceae

Representatives of the family Braarudosphaeraceae are rare or absent in most samples. They reach « few » in the Paleocene sample 6 and in the Eocene sample 27. This might be an indication, that the sites studied, during the interval studied, never were very near to the southern shore of the Thethys.

Calciosolenaceae

Two species of this family, *Scapholithus fossilis* and *S. rhombiformis* occur in a few samples only.

Calyptrosphaeraceae

Representatives of this family occur mainly from sample 21 on upwards (NP 11 & ? NP 12, Early Eocene), where they are rare to few.

Coccolithaceae

Of this family, only *Ericsonia ovalis* is consistently present and usually common. *E. subpertusa* occurs common in the Paleocene and *Cyclococcolithina gammation* few to common in the uppermost part of the sequence studied. *Chiasmolithus* reaches few in some samples, especially in the uppermost part of the Paleocene. The only *Cruciplacolithus* reaching an abundance of common and being consistenly present in the Paleocene part of the sequence studied, is *C. notus,* a species erected recently by Perch-Nielson (1977).

Cruciplacolithus notus Perch-Nielsen 1977

Pl. 8, figs. 83, 84; Pl. 12, figs. 3, 6, 9, 11, 12

Diagnosis : A species of *Cruciplacolithus* with a central cross distally attached to the rim of the central area by a counterclockwise oriented « foot » at each leg.

Description : *C. notus* has an elliptical outline and the distal and the proximal shields are composed of a varying number of elements. The legs of the central cross usually are oriented parallel to the axis of the coccolith but sometimes they shifted towards the diagonals and the assignement of the form to *Cruciplacolithus* becomes problematical. Towards the rim of the central area, the legs of the central structure turn around to form « feets » by which they are attached to the rim. These « feets » are also well distinguishable in the light microscope.

Remarks : *C. notus* is usually larger than *C. tenuis,* from which it differs through the presence of the « feets » in the former.

Occurrence : *C. notus* is consistently present and even common in the Paleocene samples at Gebel Oweina. It is certainly quite widely distributed in the Upper Danian and the rest of the Paleocene from where it was hitherto recorded as *C. tenuis.* In the type Danian of Denmark, it occurs after the first occurrence of *Chiasmolithus danicus,* while *C. tenuis* occurs already below this datum. In the South Atlantic, however, it occurs already in the upper part of NP2, and is most common in NP4 through NP6.

Discoasteraceae

Discoasters are present in almost all samples above 11 and are rare to few. Their state of preservation is usually rather poor and their determination accordingly difficult. The evolution from *Rhomboaster cuspis* to *Marthasterites bramlettei* and from the latter to *M. contortus* is well documented in the sequence studied.

Fasciculithaceae & Heliolithaceae

The near relations of the Fasciculithaceae with the Heliolithaceae and the Discoasteraceae are well visible from the plates presented here. However, better preserved material from a sequence with a higher sedimentation rate is necessary to study the evolutionary lines from the fasciculiths over the helioliths to the discoasters. The assemblages in the Late Paleocene samples studied here do not change in a « normal » way as compared to the « Tertiary Standard Zonation » (Martini 1971) and other sequences of a comparable age. The common first occurrence of fasciculiths and discoasters certainly points to a hiatus below the level of sample 11 (or an extremely condensed sequence between sample 4 and 11, unless the sample distance is not so small as indicated on figure 2). The occurrence of discoasters in 11, before the relatively common occurrence of *H. kleinpelli* in 12, also is strange. Obviously, more and closer spaced samples need to be taken to investigate, which zones really are present and which are missing and whether the seemingly « mixed » assemblages are due to reworking, burrowing or human errors.

The absence of fasciculiths and helioliths in the lowermost sample in the section at Gebel Gurnah would support its Early Eocene age.

Pontosphaeraceae

Representatives of the family Pontosphaeraceae are almost entirely restricted to the Eocene, where the few species present occur rare to few.

Prinsiaceae

Toweius and *Prinsius* are the two genera representing the Prinsiaceae in the Paleocene and Lower Eocene. Together with some Coccolithaceae they form the bulk of coccoliths present in all the samples. *Toweius craticulus* is taken in a very large sens. A new species, *T. rotundus* is introduced for the small, round forms encountered in many samples.

Toweius rotundus Perch-Nielsen n.sp.

Pl. 8, figs. 34, 35 Pl. 18, figs. 4, 15, 18, 19

Holotype : Pl. 18, fig. 15.

Type level : Early Eocene, NP 11.

Type locality : Gebel Gurnah, sample 22; Egypt.

Diagnosis : A small, circular or nearly circular form of *Toweius*.

Description : The outline of this small coccolith is circular or nearly circular. The distal and the proximal shields consists of a varying number of elements. The first wall is narrow and from the second wall, some elements continue radially into the central field, leaving small perforations inbetween them.

Remarks : *T. rotundus* is distinguished from other Toweius by its circular outline and coarse central net. *Cribrocentrum reticulatum* has only one wall and a somewhat finer central net.

Occurrence : *T. rotundus* is consistently present and sometimes even common through the Paleocene and Eocene studied here.

Rhabdosphaeraceae

Rhabdoliths are rare to few in Eocene samples, where usually only *Rhabdolithus solus* occurs.

Sphenolithaceae

Sphenoliths are present, but usually overgrown, in most samples above 11. The assemblage consists only of *S. anarrhopus* and *S. primus* in the the Paleocene. From sample 20 on upwards *S. editus*, a new species occurs, while typical *S. radians* have their first occurrence in sample 26.

Sphenolithus editus Perch-Nielsen n.sp.

Pl. 8, figs. 4, 5, 11-13, 16-18, 22-27, 43-45;
Pl. 20, figs. 5-19

Holotype : Pl. 20, fig. 12.

Type level : Early Eocene, NP 11.

Type locality : Gebel Gurnah, sample 22; Egypt.

Diagnosis : A sphenolith of largely conical outline.

Description : The proximal shield consists of a varying number of elements and in well preserved specimens, forms a short truncated cone. The lateral elements and the apical spine together form a steeper cone on top of the proximal shield. In specimens showing considerable overgrowth, the whole nannolith is cone-shaped.

Remarks : *S. editus* varies considerably in size. It is distinguished from *S. radians* by its conical shape, where *S. radians* has a more cylindrical proximal shield.

Occurrence : *S. editus* was found in the Lower Eocene from sample 20 on upwards.

Syracosphaeraceae

Ellipsolithus was the only genus found in the material studied who might belong to the Syracosphaeraceae. Besides the « normal » *E. macellus,* smaller and narrower forms were found in some of the Paleocene samples at Gebel Oweina. *E. distichus* also shows quite a variability in outline and size aswell as in the form and number of the central perforations.

Thoracosphaeraceae

Thoracosphaera is common in the Paleocene at Gebel Oweina, while it occurs less frequent in the Eocene at Gebel Gurnah. Usually, only relatively small pieces of the sphere were found.

Zygodiscaceae

Zygodiscaceae are present, usually in small numbers, in most samples in the Paleocene aswell as the Eocene. Of special interest is the presence of *Neochiastozygus saepes* in the two lowermost samples at Gebel Oweina. This species has its first occurrence in the uppermost Danian of Denmark, and there occurs together with *N. perfectus* in the lowermost, overlying Selandian. It has also been found in the Danian of Alabama (sample Alabama 2 A in Bramlette & Martini, 1964) and Haidhof, Austria. If *N. saepes* is restricted to the *E. macellus* Zone, as it seems from the occurrence sofar noted outside Denmark, this might indicate that the uppermost Danian agewise belongs to the interval of this zone, although sofar, only extremely rare specimens of *E. macellus* were found in the hundreds of Danian samples studied from the type area with its high latitude assemblage.

Forms of the Zygodiscaceae are especially common and diverse in sample 16 of the Eocene at Gebel Gurnah. The presence of very rare *Chiphragmalithus calathus* in sample 29 supports the assignement of this sample to the *M. tribrachiatus* Zone (NP 12) or the uppermost part of NP 11. The consistent presence of *Neochiastozygus junctus* in the lower Lower Eocene is surprising, since this species is usually found in the Upper Paleocene.

Incertae Sedis

Only very few forms that are not readily assignable to an existing family, were found. *Hornibrookina australis,* a species recently described from the Paleocene of the Southern Hemisphere, is very rare in samples 13 and 14. *Conococcolithus minutus* occurs sporadically in the Paleocene at Gebel Oweina.

DISCUSSION AND CONCLUSION

The transgression of the Tethys over the greater part of Egypt started in the Cenomanian and tectonic movements controlled the deposition of the different facies observed in the Upper Cretaceous and Lower Tertiary sediments in Egypt (Issawi, 1972). At the end of the Maastrichtian, a regression phase is marked by the well known hiatus occurring at the Cretaceous/Tertiary boundary. This hiatus, in the area studied, includes probably some of the uppermost Maastrichtian and the Lower and Middle Danian (see figs. 2, 4).

Strata of Paleocene age are represented in this area by the Oweina Shale Formation including the Lower Oweina Shale (= upper part of Dakhla Shale), the Upper Oweina Shale (= lower part of Esna Shale) and the interbedded Kilabiya Chalk and Tarawan Chalk units. Different facies thus represent the Paleocene which, however, is partly or completely missing at some localities. Through the finer resolution of the calcareous nannofossil zonation in the Late Paleocene, such a hiatus that could not be detected by planktonic foraminifera, is suggested in the section at Gebel Oweina.

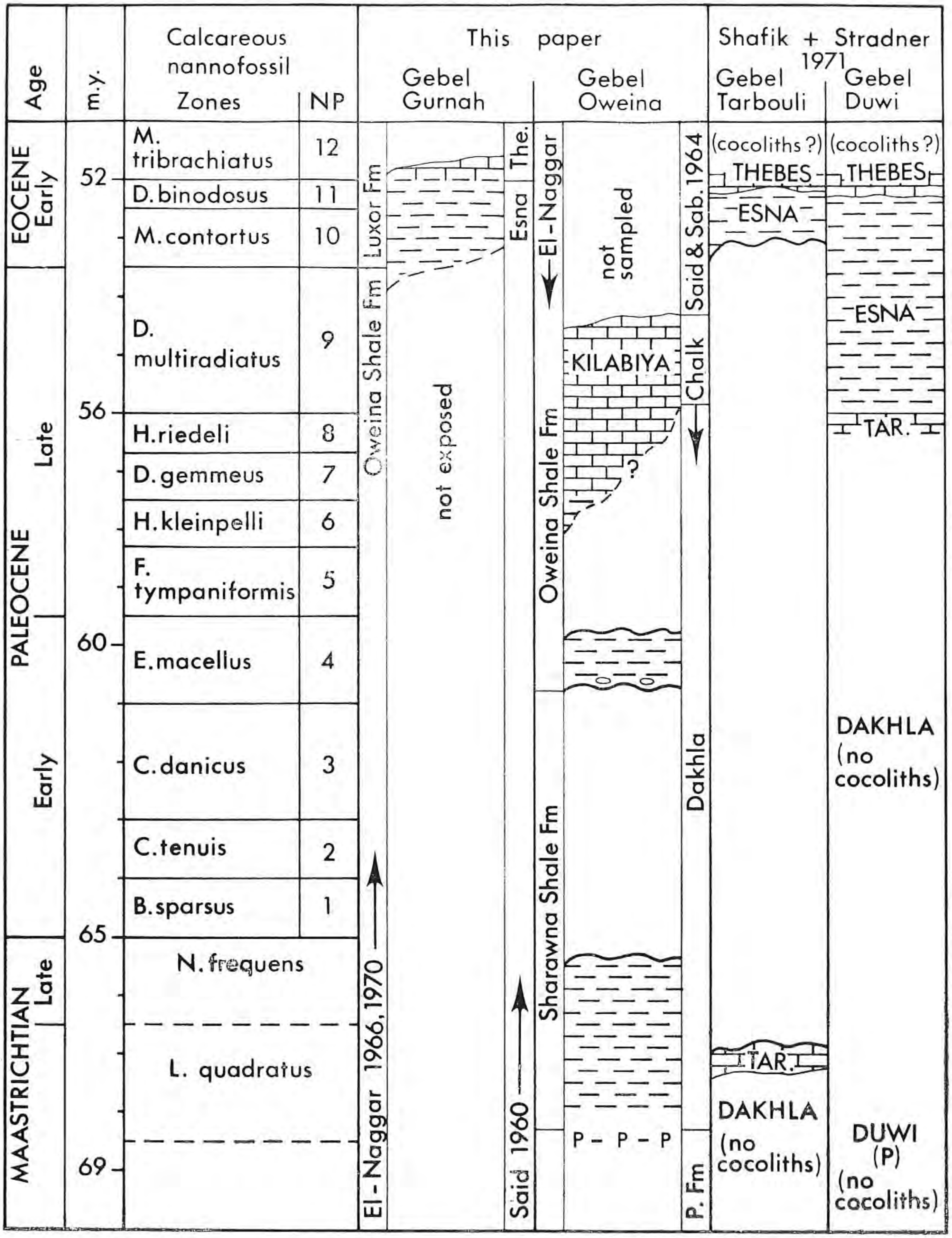

Fig. 4. Time stratigraphic and rock stratigraphic relations of the sections at Gebel Gurnah, G. Oweina, G. Tarbouli and G. Duwi.

More detailed studies of the coccoliths at other localities in Egypt are recommended to find out, how long the two hiati lasted at different localities. A more thorough distinction between lithostratigraphical and biostratigraphical use of units is needed to allow the solution of the rock-time relationships of more localities. Figure 4 shows very well the difficulties of the geologist in the field, who does not distinguish properly between time and rock units. The shales at Gebel Oweina are of Late Maastrichtian and Late Danian age; they are Late Paleocene and Early Eocene age at Gebel Gurnah and in the sections along the Red Sea coast (Shafik and Stradner, 1971). The Tarawan Chalk, if correlated with the Kilabiya Chalk as implied by Issawi (1972) is of Maastrichtian age at Gebel Tarbouli and of Late Paleocene age at Gebel Oweina.

The lithological units introduced by El-Naggar (1966, 1970) are followed in this paper, although they, too, seem not completely logic and are not « mapable units » as required for lithological units. Both El-Naggar's units (1966) and Said's mapable units (1962) are given in figure 4 for the sections at Gebel Oweina and Gebel Gurnah. Note that the age of the Thebes Limestone seems to be the same at the localities shown in figure 4. Biostratigraphical control is, however, rather poor here.

Figure 4, although the ages assigned to the coccolith zones (Perch - Nielsen, 1972) are highly unreliable in detail, nevertheless, gives an idea about the length of periods, when sedimentation occurred and how much time's worth was removed again or never deposited at all at Gebel Oweina and Gebel Tarbouli. Clearly in the interval studied here, considerably less time is represented by sediments at these two localities than by hiati. It is then surprising, how little reworking of i.e. Maastrichtian coccoliths into the younger sediments has taken place.

The relationships between the planktonic foraminiferal zones and the calcareous nannofossil zones for the Maastrichtian, the Paleocene and the Early Eocene as found in this study are shown in figures 2 and 3. The correlations found in the Lower Tertiary here are mostly similar to those given by Martini (1971).

However, with the *Globorotalia aragonensis* datum correlated with the base of the *M. tribrachiatus* Zone (Berggren, 1972), the presence of the *M. tribrachiatus* Zone should be implied by the presence of *G. aragonensis* from sample 26 on upwards in the Gebel Gurnah section. The presence of *Discoaster lodoensis* which has its first occurrence at the base of the *M. tribrachiatus* Zone (NP 12) is, however, not ascertained beyond doubt. Thus most of the sediments are assigned to the older *D. binodosus* Zone (NP 11).

Another point of divergence of correlations between coccolith and foraminiferal zones occurs in the lowermost Tertiary met with at Gebel Oweina. Here, the *E. macellus* Zone (NP 4) spans the *G. compressa - G. daubjergensis* Zone as well as the *Globorotalia angulata* Zone. It is shown by Martini (1971) to start later and even later by Berggren (1972), where it is correlated to begin in the *G. pusilla - G. angulata* Zone. This discrepancy illustrates well the remarks already made by Haq (1971) about the reliability of the first occurrence of *E. macellus* as a zonal marker over wider areas. A single specimen of *E. macellus* was found in the type Upper Danian of Denmark. This was an indication, that some of the Danian might, timewise, be correlated to the *E. macellus* Zone. The presence of two species of *Neochiastozygus* in the upper type Danian also supports this view, since Martini (1971) records the first occurrence of *Heliorthus concinnus* from the upper part of the *E. macellus* Zone. At that time, *H. concinnus* was used in a very large sense and probably included most of the Lower and Middle Paleocene forms of *Neochiastozygus* (Perch-Nielsen, 1971).

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DISCUSSION

KERDANY :

Since you have been dealing with Gebel Oweina which is the type locality of the Esna Shales as defined by Beadnell 1905 I am surprised that you did not study them, too.

PERCH-NIELSEN :

This might be explained by the fact, that this study was originally started because of my personal interest in the Cretaceous/Tertiary boundary. I am unaware of the reasons for which my coauthors choose to supply me with samples of the incomplete Esna Shale section at Gebel Gurnah instead of the type section at Gebel Oweina.

BARAKAT :

We agree that the type Esna Shale section of G. Oweina should be studied, and it is still under study.

KERDANY :

Why do you use El Naggar's lithologic classification ?

PERCH-NIELSEN :

We use it in this paper, because my coauthors prefer it. Myself I have some reservations about it, since El Naggar's boundaries between his rock units are not lithological but rather biostratigraphical brakes and the units seem thus not mappable as required for rock units.

BARAKAT :

We use El Naggar's lithologic classification because the rock-stratigraphic units proposed by El Naggar are well defined in the studied area and could be traced from one locality to the other.

KERDANY :

The presence of the *Gr. velascoensis* Zone at the base of the Gebel Gurnah section is highly unlikely and surprising since this section has been studied extensively by many authors in the last few years and none of them found it. As a matter of fact a sample taken from the bottom of an approx. 20 m deep water well digged in Thebes close to the base of this section was examined by W.A. Berggren who concluded that the section did not reach the Paleocene. How well established is the presence of the *D. multiradiatus* Zone ?

PERCH-NIELSEN :

My co-authors did the foram-work and I will transmitt this question to them. As the first occurrence of *M. bramlettei* defines the base of the *M. contortus* Zone and thus the base of the Eocene, the presence or absence of Paleocene cannot be definitely established from a nannologist's point of view, because in the questionable sample (14), rare specimens of *R. cuspis* occur together with transitional forms to *M. bramlettei*. Actually the whole assemblage of this sample has a Eocene rather than a Paleocene aspect.

BARAKAT :

The datum levels used by many authors (Bandy, 1964; Jenkins 1965; Berggren 1964, 1969, 1971) are applied in our study. *Pseudohastigerina wilcoxensis* (Cushman & Ponton) is not encountered in the questionable (14) sample, and there is no trace of key elements dating the Lower Eocene. Thus the Paleocene - Lower Eocene boundary is traced at the outbreak of *Pseudohastigerina wilcoxensis* and the extinction of *G. velascoensis*. A slight paleontologic break is suspected at the boundary between the Upper Paleocene (Landenian) and the Lower Eocene (Ypresian) at G. Gurnah.

KERDANY :

From your presentation it is not really clear wether you have actually found the species *A. mayaroensis* or wether the presence of this zone was implied on the basis of the presence of *N. frequens* and the assemblage of *G. contusa* and *G. esnehensis*.

PERCH-NIELSEN :

I am very sorry that I cannot answer your question, since I have no rangechart of the forams. However, I will be glad to pass your question on to my co-authors.

BARAKAT :

Our concept of the *A. mayaroensis* Zone corresponds to that of Beckmann et *al.* (1969). This zone is recognised by the presence of the zonal marker (very rare in our sample studied) in addition to other characteristic planktonic foraminiferal species. However, *A. mayaroensis* has been recorded at G. Oweina section by Krasheninnikov & Ponikarov (1965) and El Naggar (1966).

PLATE 1

Lightmicroscope photographs of Maastrichtian calcareous nannofossils.
Magnification ca 2000 ×

1, 2. — *Eiffellithus parallelus* Perch-Nielsen.
3, 4. — *Eiffellithus turriseiffeli* (Deflandre) Reinhardt.
5, 6. — *Chiastozygus amphipons* (Bramlette & Martini) Gartner.
7, 8. — *Corollithion ? madagaskarensis* Perch-Nielsen.
9, 10. — *Chiastozygus litterarius* (Gorka) Manivit.
10, 11. — *Reinhardtites mirabilis* Perch-Nielsen.
13, 14. — *Ahmuellerella octoradiata* (Gorka) Reinhardt.
15, 16. — *Staurolithites bochotnicae* (Gorka) Reinhardt.
17, 18. — *Parhabdolithus angustus* (Stradner) Bukry.
19, 20. — *Zygodiscus sigmoides* Bramlette & Sullivan.
21, 22. — *Zygodiscus spiralis* Bramlette & Martini.
23. — *Tranolithus* ? sp. 1.
24. — *Zygolithus tarboulensis* Shafik & Stradner.
25. — *Glaukolithus* sp. 1.
26. — *Glaukolithus* cf. *G. diplogrammus* (Deflandre) Reinhardt.
27. — *Staurolithites* sp. 1.
28. — *Staurolithites* sp. 2.
29, 30. — *Parhabdolithus splendens* (Deflandre) Noel.
31, 32. — *Biscutum constans* (Gorka) Black.
33, 34. — *Watznaueria barnesae* (Black) Perch-Nielsen.
35, 36. — *Discorhabdus ignotus* (Gorka) Perch-Nielsen.
37, 38. — *Prediscosphaera cretacea* (Archangelsky) Gartner.
39, 40. — *Prediscosphaera stoveri* Perch-Nielsen.
41, 42. — *Prediscosphaera honjoi* Bukry.
43, 44. — *Pseudomicula quadrata* n.gen.n.sp.
45-47. — *Micula staurophora* (Gardet) Stradner.
48, 49. — *Cribrosphaerella ehrenbergi* (Archangelsky) Deflandre.
50, 51. — *Arkhangelskiella cymbiformis* Veksina.
52, 53. — *Kamptnerius percivalli* Bukry.
54, 55. — *Zygodiscus ? pseudanthophorus* Bramlette & Martini.
56, 57. — *Lithraphidites quadratus* Bramlette & Sullivan.
58, 59. — *Tetralithus aculeus* (Stradner) Gartner.
60, 61. — *Nephrolithus frequens* Gorka.
62, 63. — Gen. et Sp. indet.
64, 65. — *Watznaueria* sp. 1.
66, 67. — *Cretarhabdus decorus* (Deflandre) Bramlette & Martini.
68-71. — *Cylindralithus oweinae* Perch-Nielsen.
72, 73. — *Stradneria crenulata* (Bramlette & Martini) Noel.
74, 75. — *Stradneria limbicrassa* Reinhardt.
76, 77. — *Heterorhabdus sinuosus* Noel.

K. PERCH-NIELSEN, A. SADEK, M.G. BARAKAT & F. TELEB

PL. 1

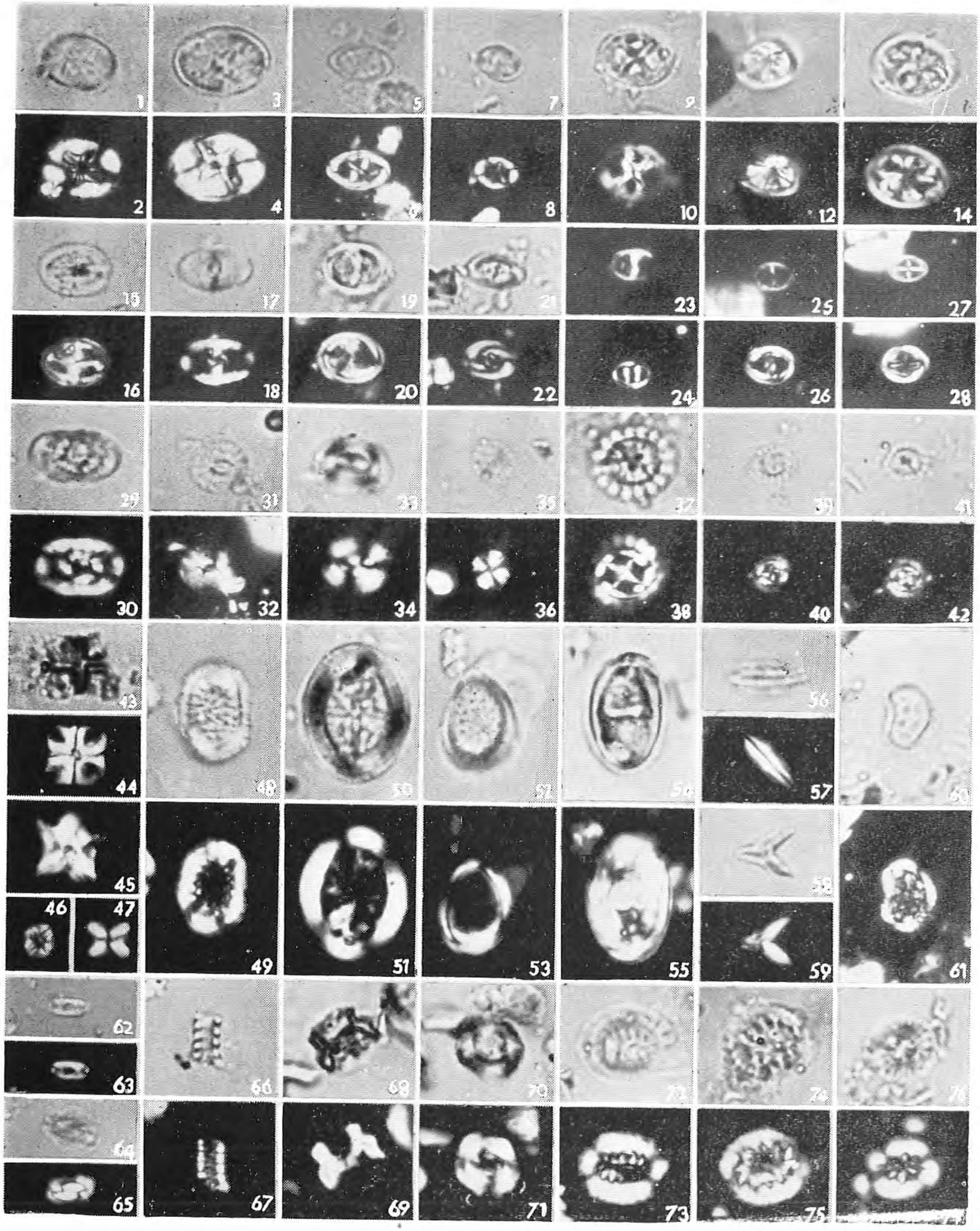

PLATE 2

Late Maastrichtian coccoliths from sample 7

1, 2 — *Archangelskiella cymbiformis* Veksine, distal and proximal view. 7800 ×, 6900 ×.

3, 5, 6. — *Kamptnerium percivalli* Bukry, distal views and proximal view (5). 7700 ×, 9500 ×, 6600 ×.

4, 7. — *Nephrolithus frequens* Gorka, proximal and distal view. 11700 ×, 11000 ×

8, 9. — *Cribrosphaerella ehrenbergi* (Archangelsky) Deflandre, distal and proximal view. 9200 ×, 10000 ×.

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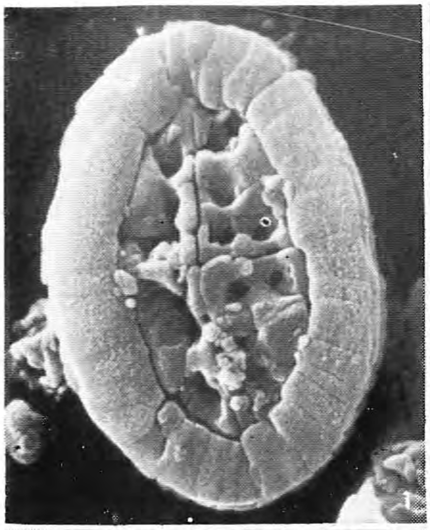

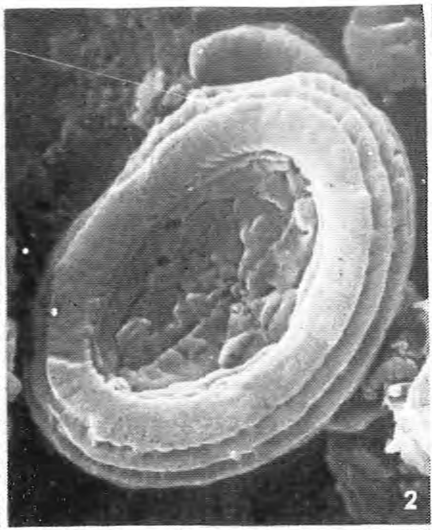

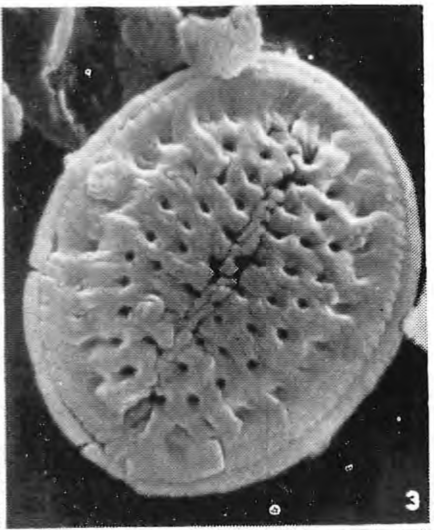

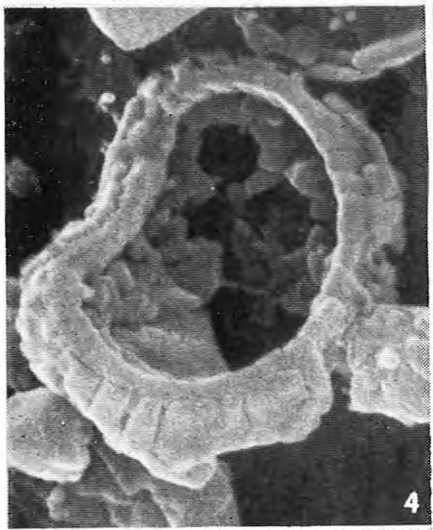

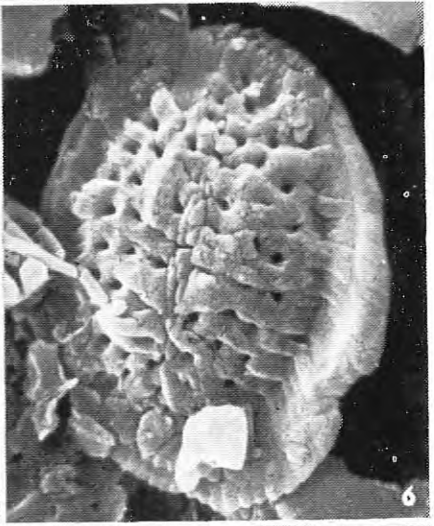

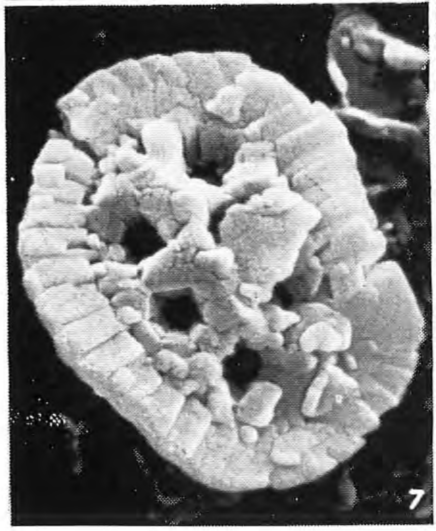

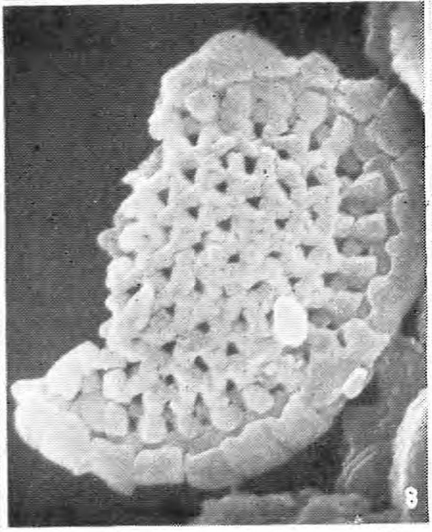

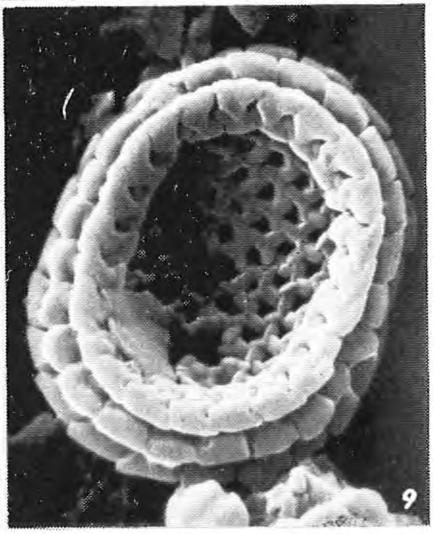

PLATE 3

Late Maastrichtian coccoliths from sample 7

1-7. — *Prediscosphaera cretacea* (Archangelsky) Gartner, distal views and proximal view (7). 10 000 ×, 10 000 ×, 9 000 ×, 8 700 ×, 9 100 ×, 12 200 ×, 10 400 ×.
8. — *Prediscosphaera* cf. *P. honjoi* Bukry, distal view. 12 800 ×.
9. — *Prediscosphaera* sp., seen from the side. 11 200 ×.
10, 11. — *Prediscosphaera bukryi* Perch-Nielsen, distal views. 14 000 ×, 14 400 ×.
12. — *Prediscosphaera stoveri* Perch-Nielsen, distal view. 14 000 ×.

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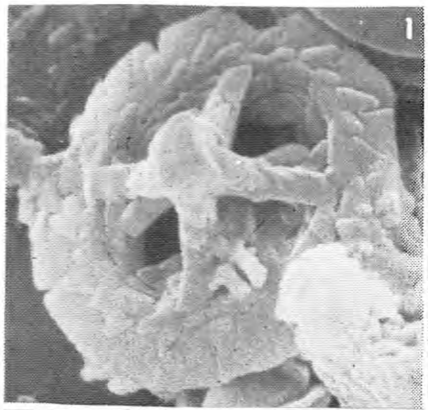
PL. 3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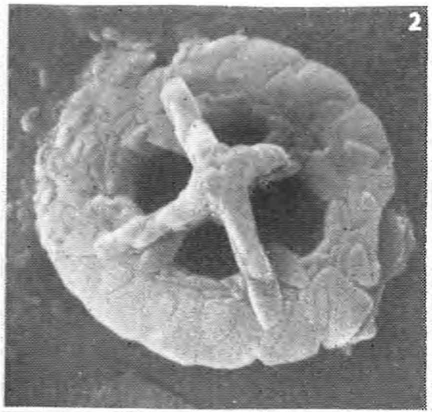
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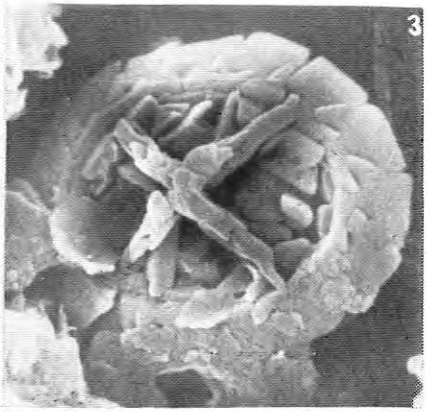
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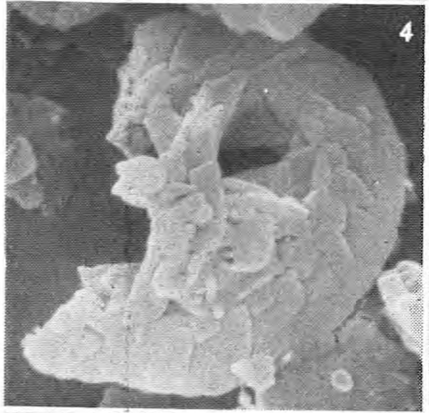
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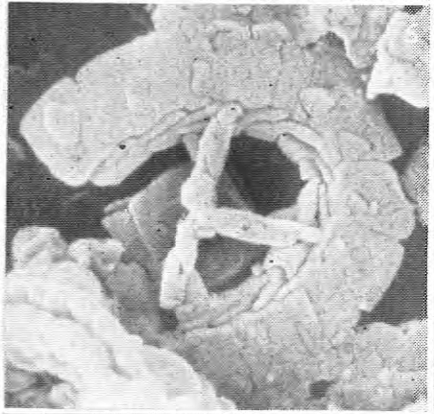
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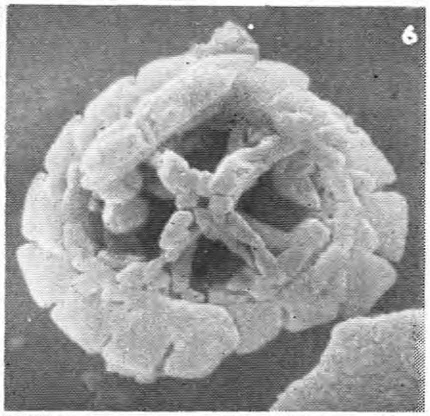
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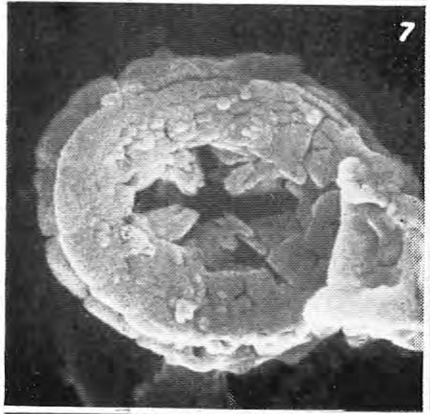
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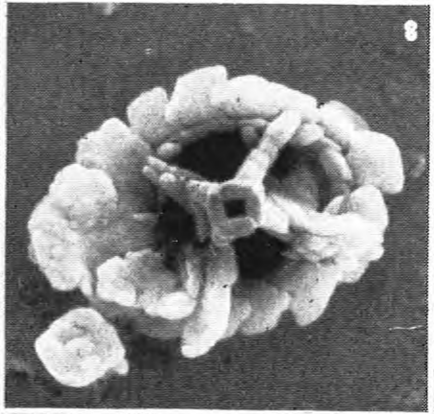
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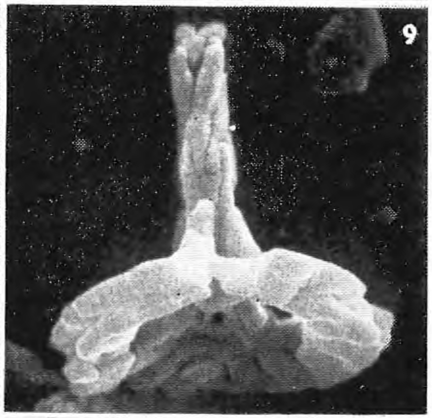
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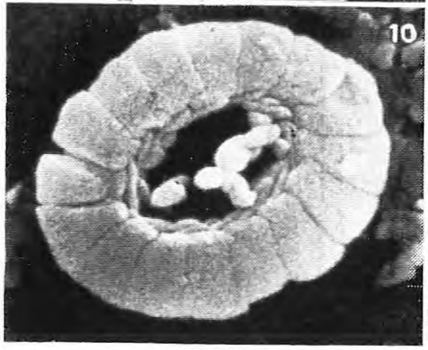
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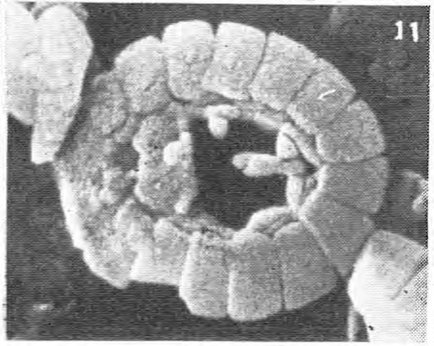
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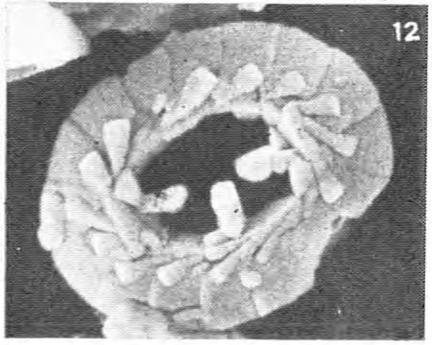
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PLATE 4

Late Maastrichtian coccoliths from sample 7

1, 4, 5. — *Cretarhabdus granulatus* (Reinhardt) Reinhardt, distal views. 10 000 ×, 9 300 ×, 8 600 ×.

2. — *Stradneria limbicrassa* Reinhardt, distal view. 8 000 ×.

3, 7, 10. — *Reinhardtites mirabilis* Perch-Nielsen, distal oblique and proximal view. 10 600 ×, 9 900 ×, 9 000 ×.

6, 9. — *Stradneria crenulata* (Bramlette & Martini) Noel, distal and proximal view. 10 000 ×, 10 600 ×.

8 — *Parhabdolithus angustus* (Stradner) Bukry, distal view. 9 000 ×.

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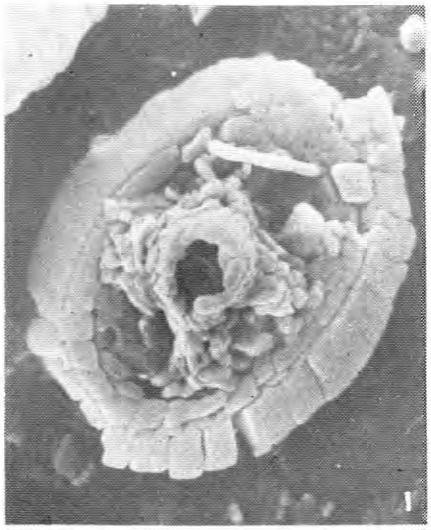
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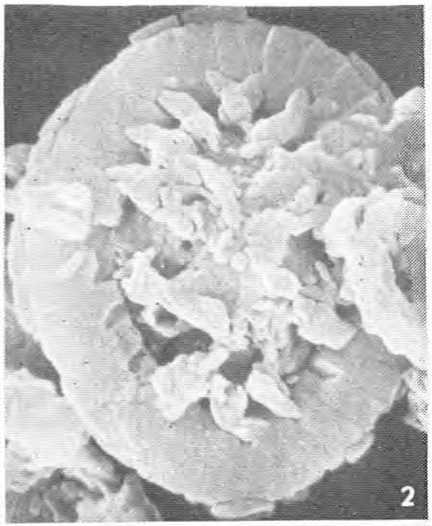
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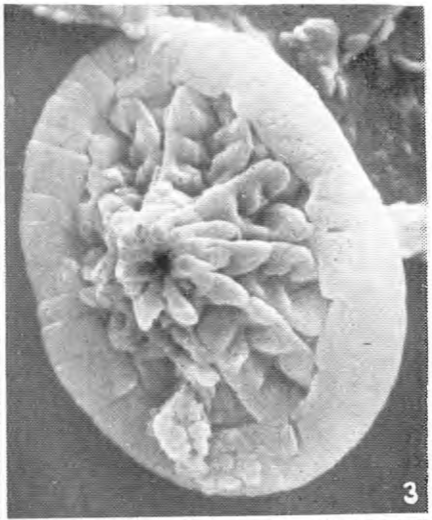
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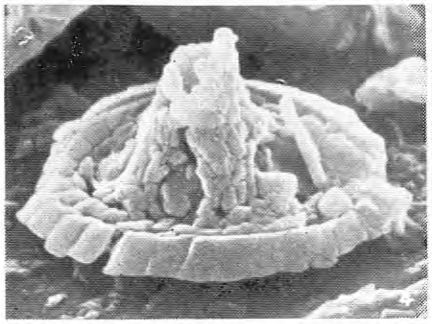
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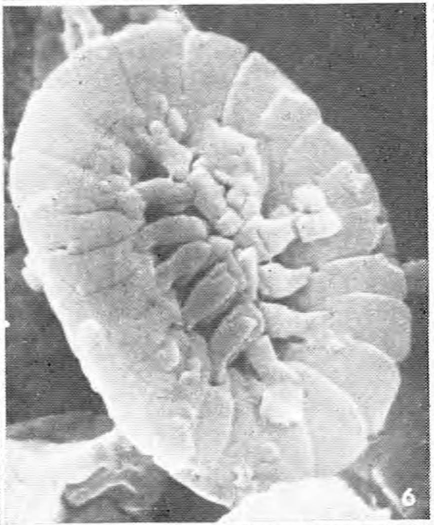
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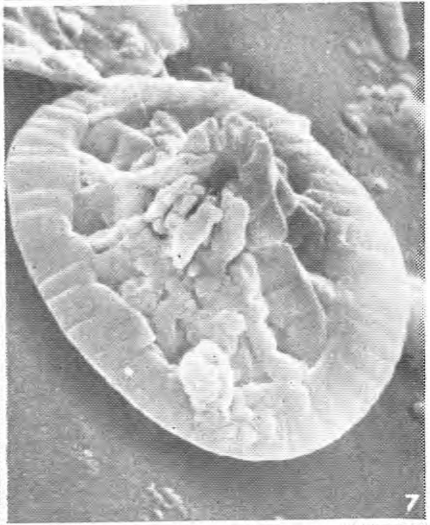
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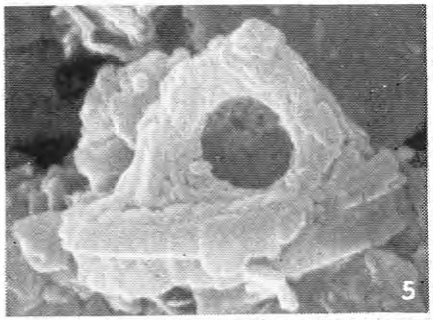
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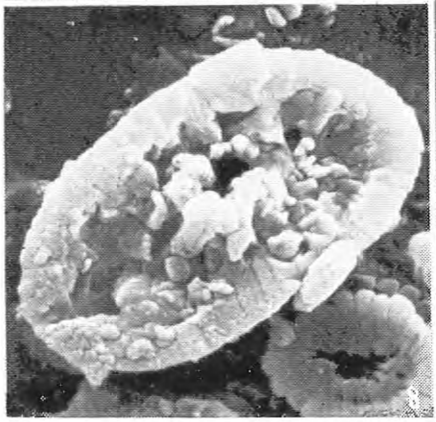
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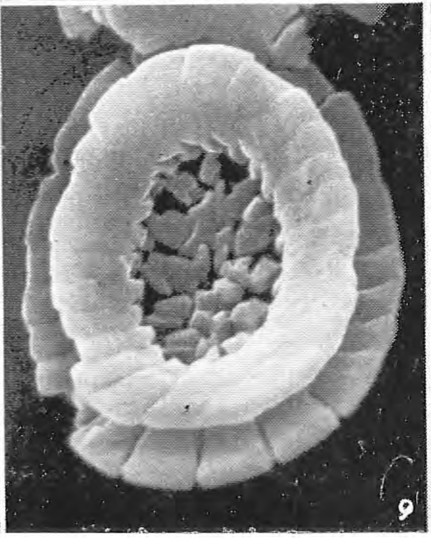
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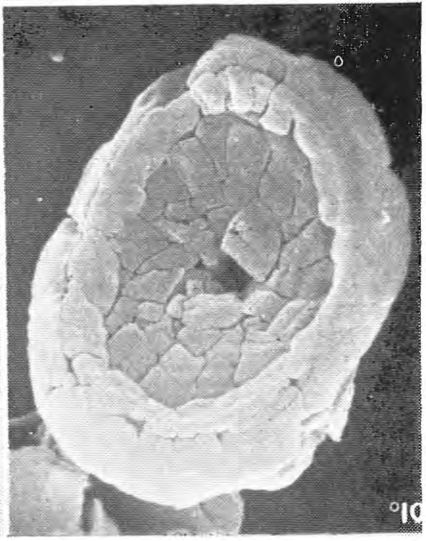
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PLATE 5

Late Maastrichtian calcareous nannofossils from sample 7

1, 5. — *Eiffelithus* cf. *E. turriseiffeli* (Deflandre) Reinhardt, distal views. 10 700 ×, 11 800 ×.

2. — *Lithraphidites carniolensis* Deflandre. 7 000 ×.

3, 4. — *Lithraphidites quadratus* Bramlette & Martini. 10 000 ×, 10 000 ×.

6, 7, 9. — *Glaukolithus* cf. *diplogrammus* (Deflandre) Reinhardt, proximal views and distal view (*9*). 10 600 ×, 10 600 ×, 10 600 ×

8, 10, 11. — *Zygolithus tarboulensis* Shafik & Stradner, distal and oblique views. 10 000 ×, 9 500 ×, 9 700 ×.

12, 16. — *Zygodiscus sigmoides* Bramlette & Sullivan, distal and proximal view. 10 000 ×, 10 700 ×.

13, 17. — *Chiastozygus litterarius* (Gorka) Manivit n. comb., distal and proximal view. 8 300 ×, 10 600 ×.

14, 18, 20. — *Chiastozygus amphipons* (Bramlette & Martini) Gartner, proximal and oblique views. 7 500 ×, 9 400 ×, 8 400 ×.

15. — *Chiastozygus* cf. *C. propagulis* Bukry, proximal view. 11 600 ×.

19, 21. — *Staurolithites* sp. 2, distal and proximal view. 8 200 ×, 8 400 ×.

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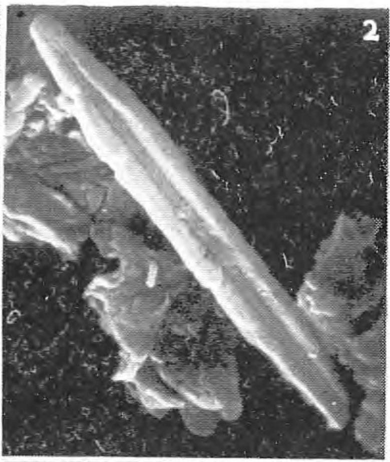
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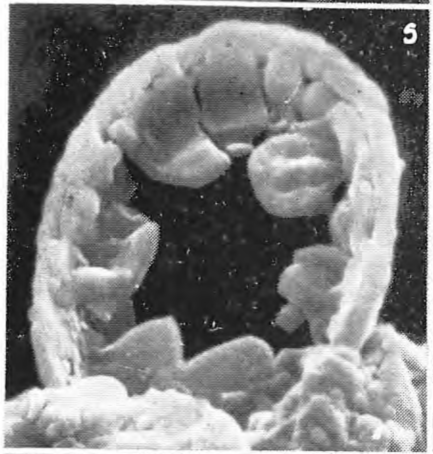
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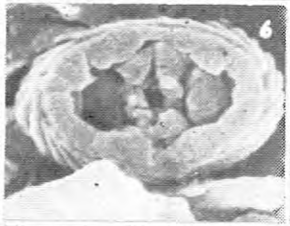
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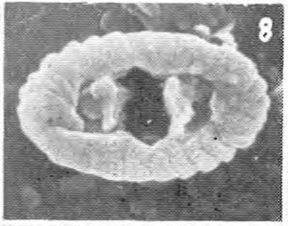
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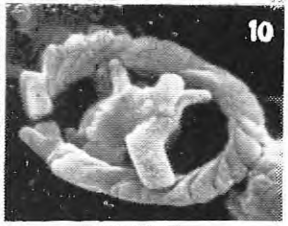
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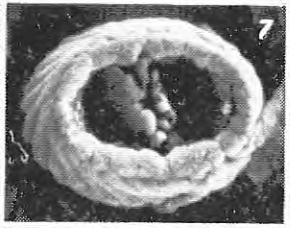
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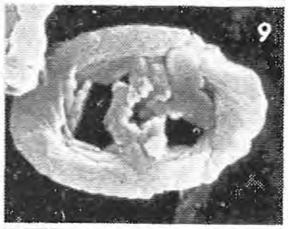
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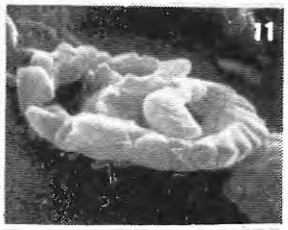
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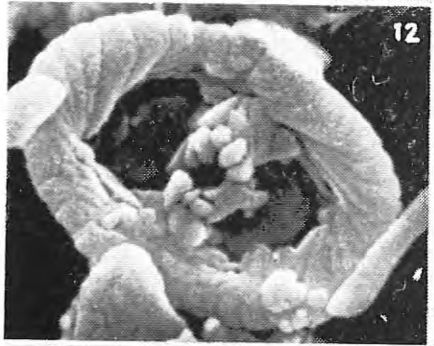
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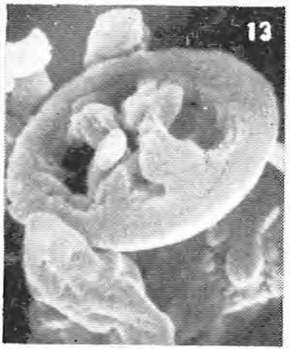
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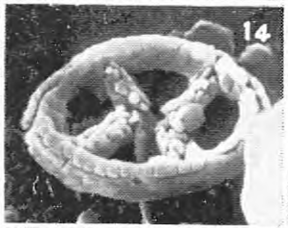
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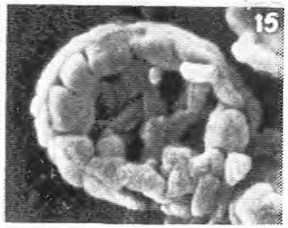
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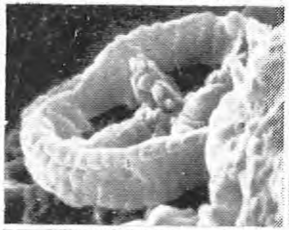

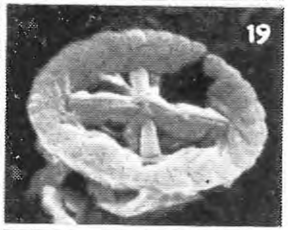
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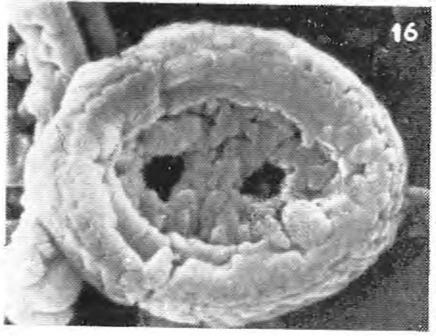
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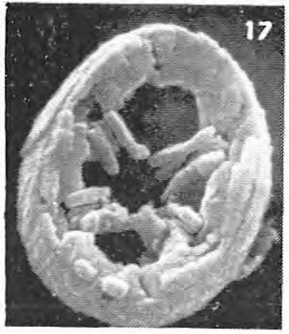
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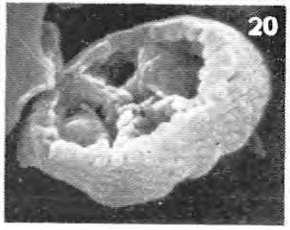
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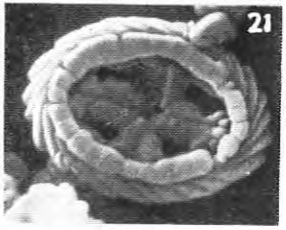
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PLATE 6

Late Maastrichtian coccoliths from sample 7

1-5. — *Cylindralithus oweinae* Perch-Nielsen. 9 400 ×, 8 000 ×, 10 000 ×, 8 000 ×. 7 100 ×.

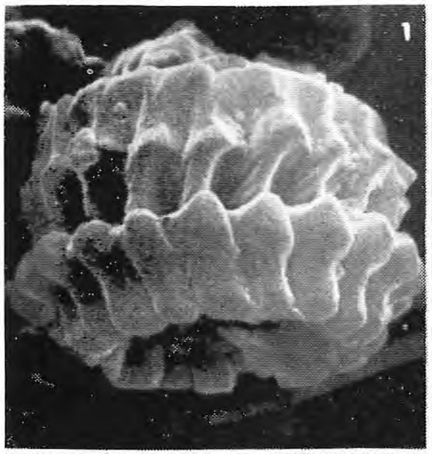
6. — *Watznaueria biporta* Bukry, distal view. 7 900 ×.

7. — *Markalius perforatus* Perch-Nielsen, distal view. 11 100 ×.

8, 11. — *Biscutum constans* (Gorka) Black, distal and proximal view. 10 000 ×, 9 900 ×.

9, 12. — *Watznaueria barnesae* (Black) Perch - Nielsen, distal and proximal view. 10 700 ×, 13 700 ×.

10. — *Markalius* sp., distal view. 9 400 ×.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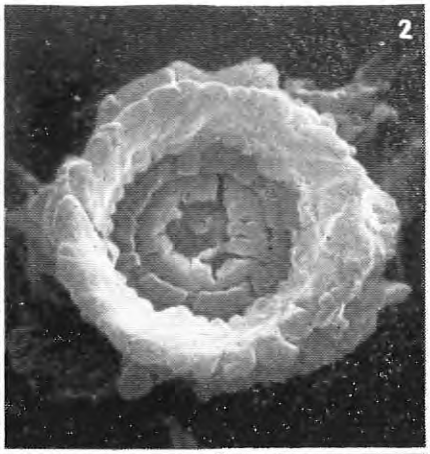
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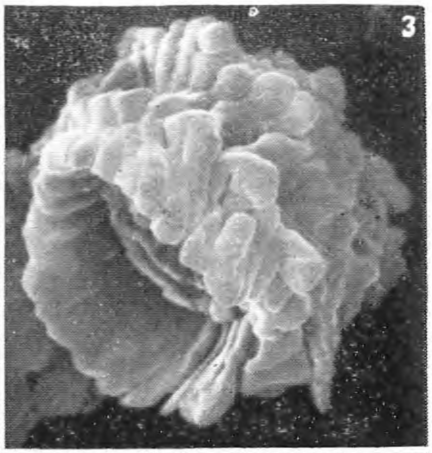
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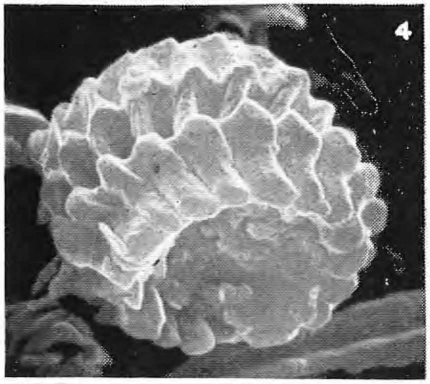
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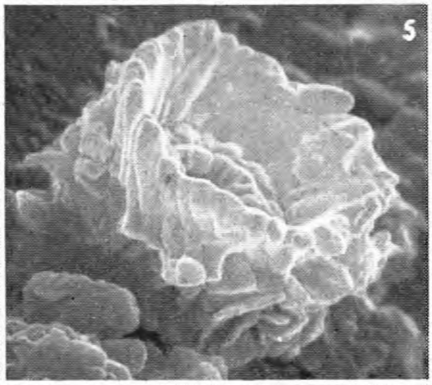
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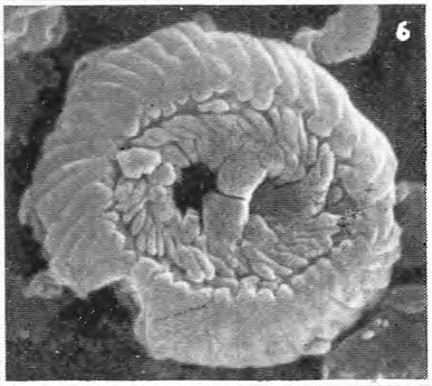
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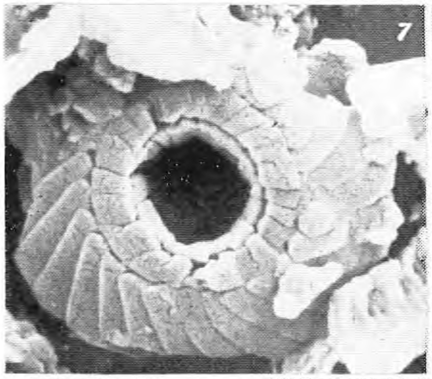
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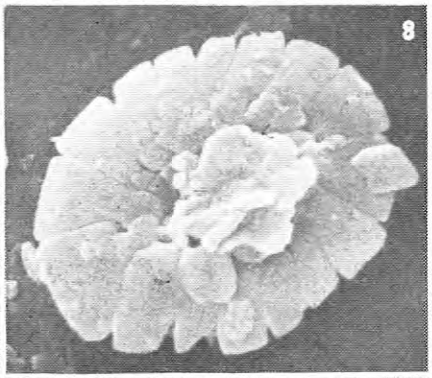
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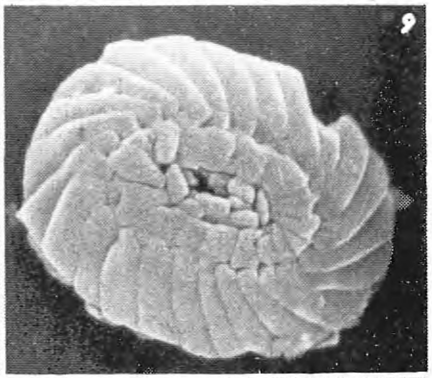
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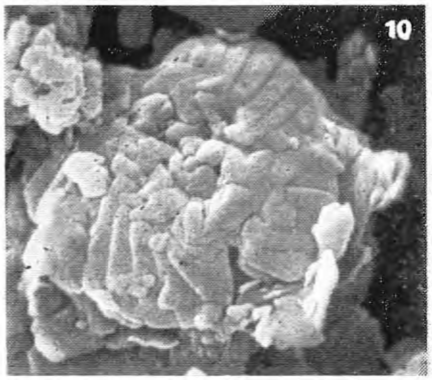
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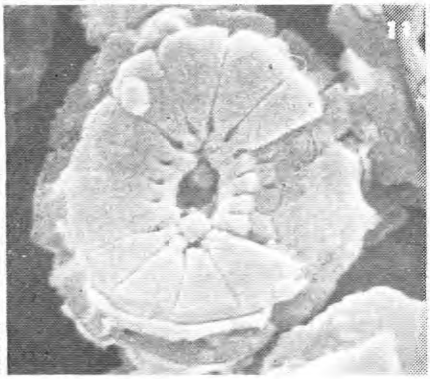
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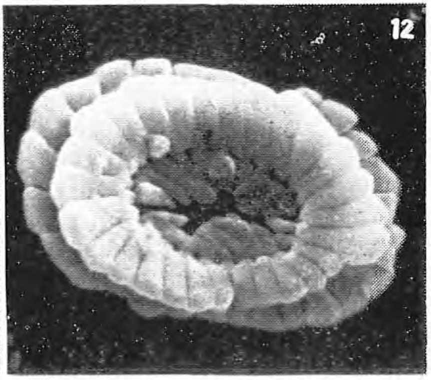
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PLATE 7

Late Maastrichtian calcareous nannofossils from sample 7

1, 2, 4, 5, 7, 8, 10. — *Micula staurophora* (Gardet) Stradner, different views and preservation. 10 700 ×, 9 400 ×, 11 100 ×, 9 700 ×, 9 200 ×, 14 600 ×, 7 300 ×.

3, 6, 9. — *Pseudomicula quadrata* n.gen.n.sp., different views. 9 700 ×, 7 900 ×, 8 100 ×, (*6, 9*) : holotype.

11. — *Corollithion* sp. 15 500 ×.

12. — Gen et Sp. indet. 3.850 ×.

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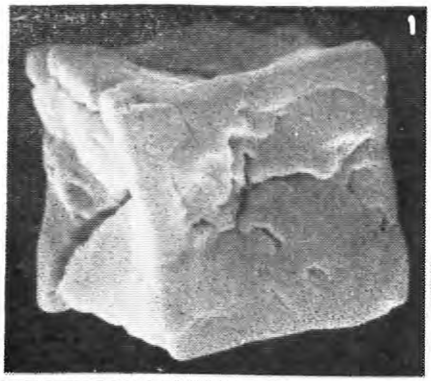
PL. 7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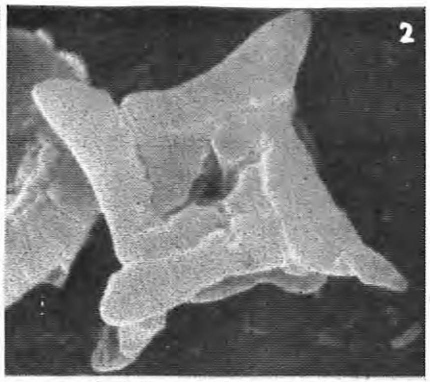
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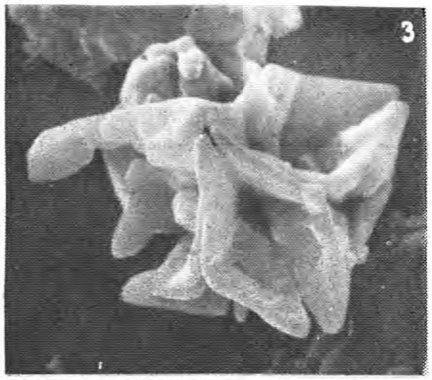
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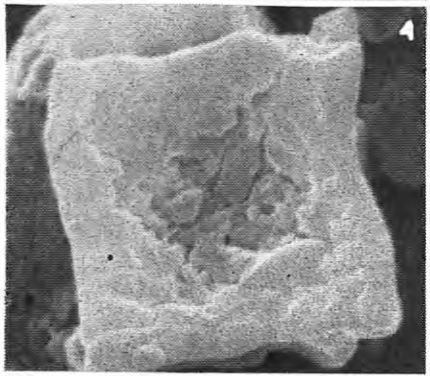
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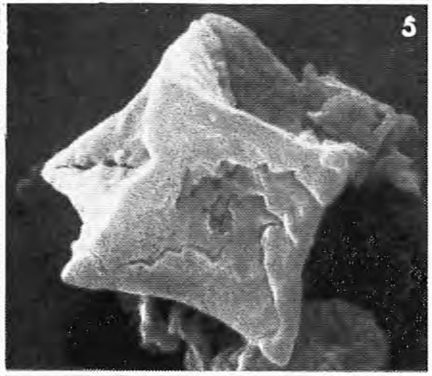
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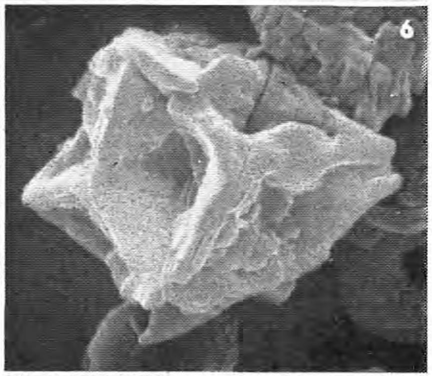
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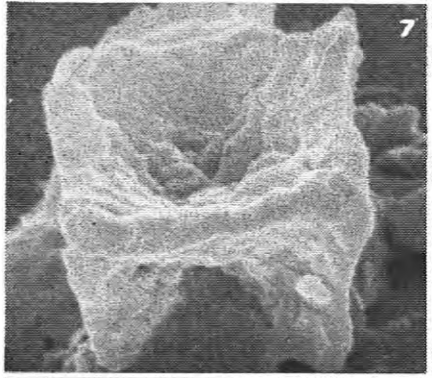
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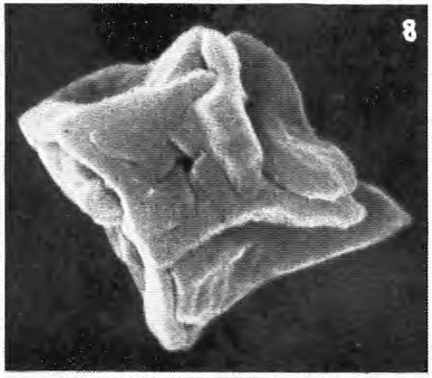
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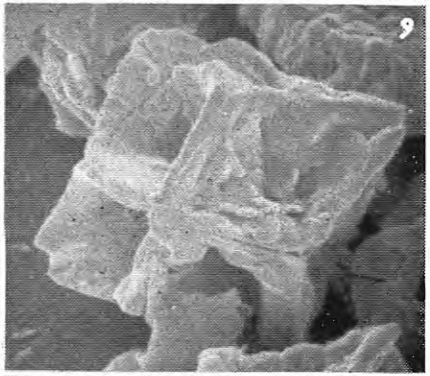
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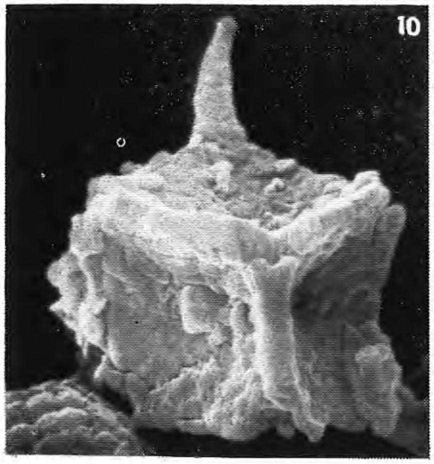
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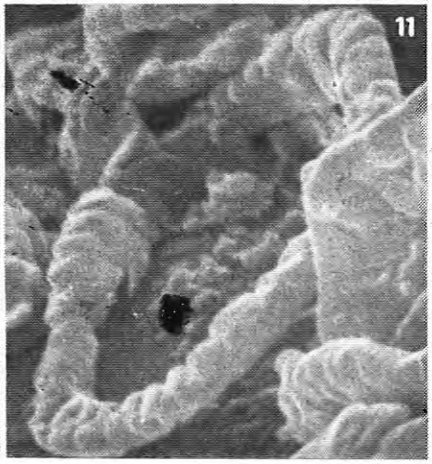
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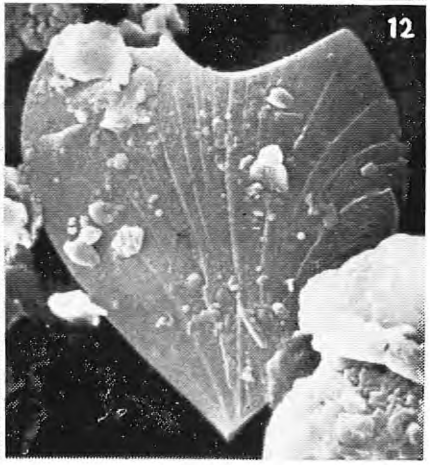
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PLATE 8

Magnification ca 2 000 ×

1-3, 14, 15, 28-38. — *Sphenolithus* sp. 1. (*Sphenolithus conspicuus* Martini 1976).
4, 5, 11-13, 16-18, 22-27, 43-45. — *Sphenolithus editus* n.sp.
6-8, 19-21. — *Sphenolithus radians* Deflandre.
9, 10. — *Sphenolithus* sp. 2.
31-33. — *Sphenolithus* sp. 3.
34, 35. — *Toweius* rotundus Perch-Nielsen n. sp.
36, 37. — *Markalius variabilis* Perd-Nielsen 1977.
38. — *Conococcolithus minutus* Hay & Mohler.
39, 40. — *Cyclococcolithina gammation* (Bramlette & Sullivan) Wilcoxon.
41, 42. — *Cyclococcolithina robusta* (Bramlette & Sullivan) Gartner.
46, 47. — *Sphenolithus primus* Perch-Nielsen.
48-50. — *Sphenolithus anarrhopus* Bukry & Bramlette.
51, 52. — *Rhabdosphaera* cf. *R. truncata* Bramlette & Sullivan.
53, 54. — *Rhabdolithus solus* Perch-Nielsen.
55, 56. — *Toweius eminens* (Bramlette & Sullivan) Perch-Nielsen.
57, 58. — *Cyclococcolithina* sp. 1.
59, 60. — *Hornibrookina australis* Edwards & Perch-Nielsen.
61, 62. — *Campylosphaera eodela* Bukry & Percival.
63, 64. — *Cruciplacolithus subrotundus* Perch-Nielsen.
65, 66. — *Chiasmolithus* sp. 1.
67, 68. — *Chiasmolithus* ? sp. 2.
69, 70. — *Chiasmolithus eograndis* Perch-Nielsen.
71, 72. — *Ericsonia subpertusa* Hay & Mohler.
73-76. — *Chiasmolithus nitidus* Perch-Nielsen.
77, 78. — *Chiasmolithus bidens* (Bramlette & Sullivan) Hay & Mohler.
79, 80. — *Chiasmolithus consuetus* (Bramlette & Sullivan) Hay & Mohler.
81, 82. — *Chiasmolithus solitus* (Bramlette & Sullivan) Locker.
83, 84. — *Cruciplacotithus notus* n.sp.

K. PERCH-NIELSEN, A. SADEK, M.G. BARAKAT & F. TELEB PL. 8

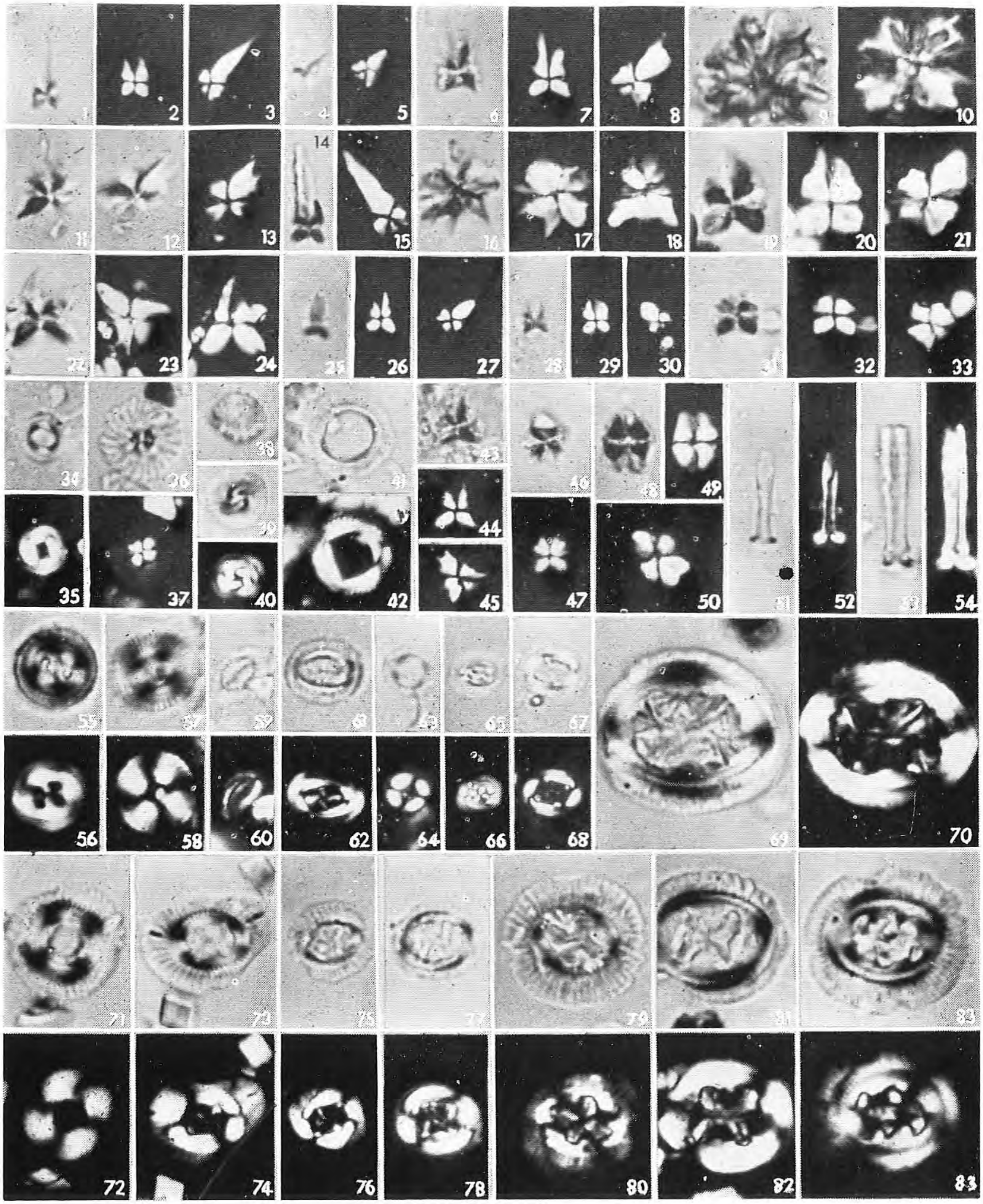

PLATE 9

Magnification ca 2 000 ×

1, 2. — *Discoasteroides bramlettei* Bukry & Percival.
3, 4. — *Fasciculithus* sp.
5, 6 25-28. — *Bomolithus elegans* Roth. (?)
7, 8, 11-14. — *Heliolithus kleinpelli* Sullivan.
9, 10. — *Heliolithus* ? *cantabriae* Perch-Nielsen.
15, 16. — *Fasciculithus tympaniformis* Hay & Mohler.
17, 18. — *Fasciculithus involutus* Bramlette & Sullivan.
19, 20. — *Fasciculithus billii* Perch-Nielsen.
21, 22. — *Fasciculithus bobii* Perch-Nielsen.
23, 24. — *Fasciculithus* sp.
29, 30. — *Thoracosphaera operculata* Bramlette & Martini.
31. — *Fasciculithus* sp. 2.
32, 33. — *Scapholithus fossilis* Deflandre.
34, 35. — *Sphenolithus primus* Perch-Nielsen.
36-38. — *Fasciculithus* sp. 1.
39, 40. — Gen et Sp. indet.
41, 42. — *Micrantholithus* sp.
43. — *Discoaster gemmeus* Stradner.
44, 45. — *Micrantholithus* flos Deflandre.
46, 47. — *Discoaster* cf. *D. bifax* Bukry, sideview.
48. — *Discoaster salisburgensis* Stradner.
49, 50. — *Discoaster multiradiatus* Bramlette & Riedel.
51. — *Discoaster binodosus* Martini.
52, 53. — *Marthasterites bramlettei* Brönnimann & Stradner.
54, 55. — *Marthasterites contortus* (Stradner) Deflandre.
56-58. — *Polycladolithus* ? sp.

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PL. 9

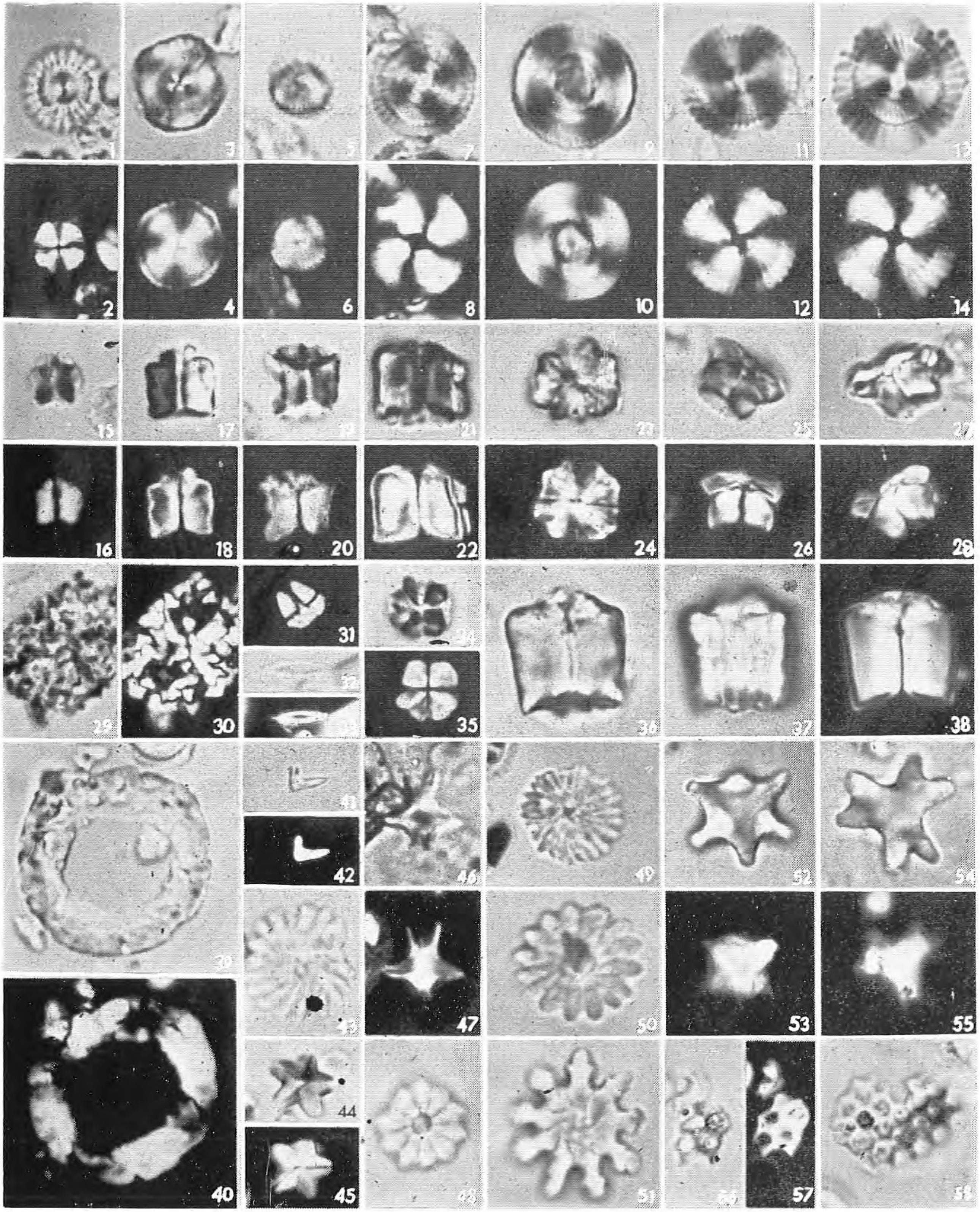

PLATE 10

Manification ca 2 000 ×

1, 2. — *Zygrhablithus* ? sp.
3-6. — *Semihololithus* cf. *S. kerabyi* Perch-Nielsen.
7-11. — *Zygrhablithus bijugatus* (Deflandre) Deflandre.
12-17. — *Semihololithus* ? sp.
18, 19. — *Neochiastozygus* sp.
20, 21. — *Neochiastozygus saepes* Perch-Nielsen.
22, 23. — *Neochiastozygus* sp. 1.
24-27, 30-33. — *Neochiastozygus distentus* (Bramlette & Sullivan) Perch-Nielsen.
28, 29. — *Neochiastozygus junctus* (Bramlette & Sullivan) Perch-Nielsen.
34, 35. — *Neochiastozygus* cf. *N. denticulatus* (Perch-Nielsen) Perch-Nielsen.
36. — *Neococcolithes* cf. *N. dubius* (Deflandre) Black.
37-40. — *Neochiastozygus* sp. 2.
41, 42. — *Neochiastozygus chiastus* (Bramlette & Sullivan) Perch-Nielsen.
43, 44. — *Neochiastozygus perfectus* Perch-Nielsen.
45-48. — *Chiphragmalithus calathus* Bramlette & Sullivan.
49, 50. — *Transversopontis* sp. 1.
51, 52. — *Discolithina pectinata* (Bramlette & Sullivan) Levin.
53, 54. — *Transversopontis* cf. *T. rectipons* (Haq) Roth.
55, 56. — *Pontosphaera rimosa* (Bramlette & Sullivan) n.comb.
57, 58. — *Zygodiscus* ? sp.
59, 60. — *Pontosphaera versa* (Bramlette & Sullivan) n.comb.
61, 62. — *Transversopontis* cf. *T. exilis* (Bramlette & Sullivan) Perch-Nielsen.
63, 64. — *Lophodolithus* ? sp.
65, 66. — *Zygodiscus plectopons* Bramlette & Sullivan.
67, 68. — *Lophodolithus nascens* Bramlette & Sullivan.
69, 70, 73, 74. — *Ellipsolithus distichus* s.l. (Bramlette & Sullivan) Sullivan.
71, 72, 75, 76. — *Ellipsolithus macellus* s.l. (Bramlette & Sullivan) Sullivan.

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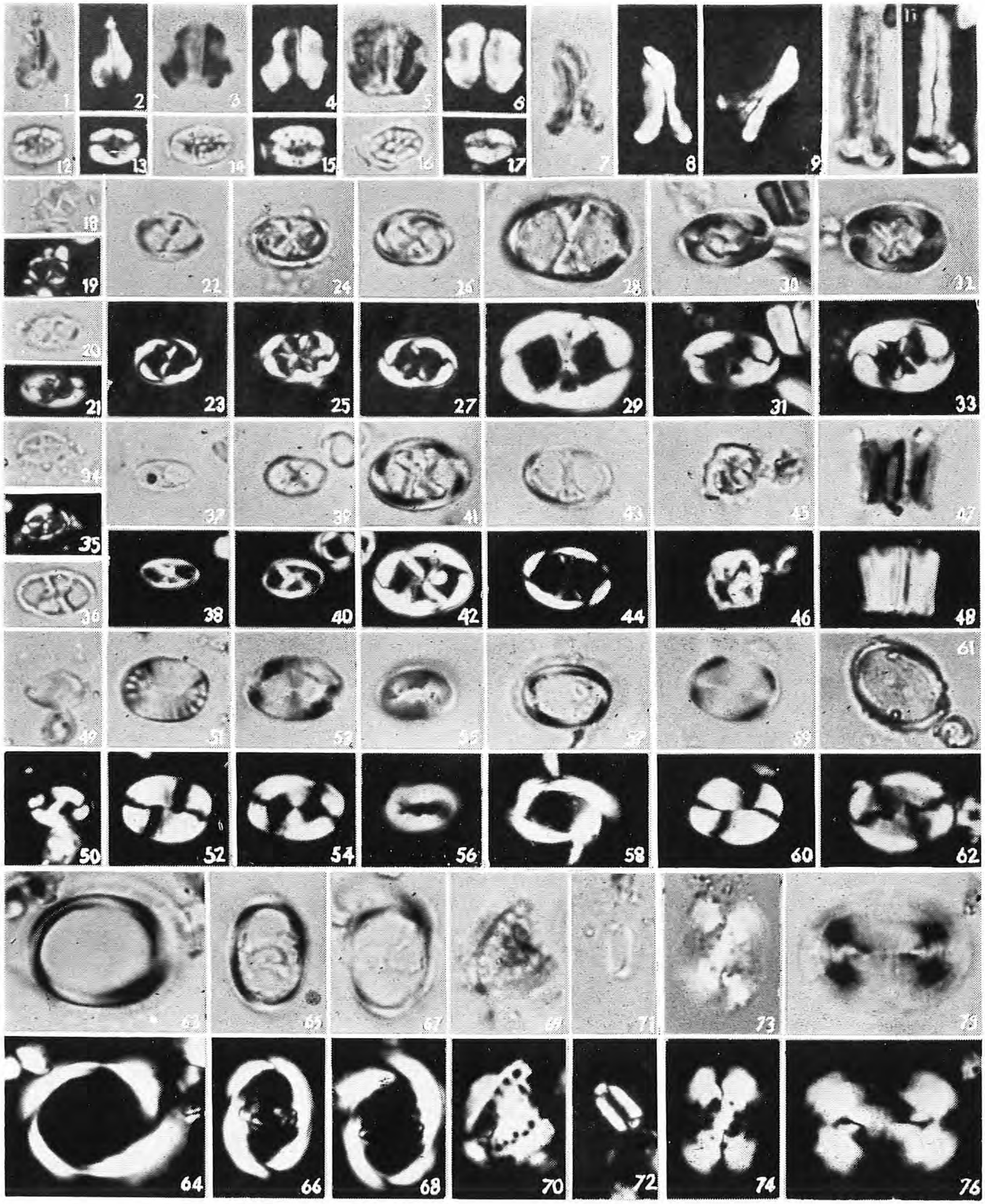


PLATE 11

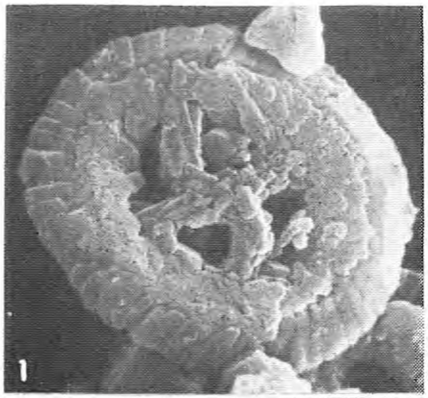
1, 4. — *Chiasmolithus bidens* (Bramlette & Sullivan) Hay & Mohler, distal and proximal view. 6 500 ×, 6 500 ×; sample 11.

2, 5. — *Chiasmolithus* ? sp., distal and oblique view. 6 400 ×, 7 500 ×; sample 13.

3, 6-9, 12. — *Chiasmolithus nitidus* Perch-Nielsen, distal views. 5 800 ×, 12 000 ×, 7 300 ×; 7 200 ×; samples 27, 22, 13, 11. Proximal views. 5 400 ×, 8 300 ×; sample 11.

10. — *Chiasmolithus danicus* (Brotzen) Hay & Mohler, distal view. 8 200 ×; sample 11.

11. — *Chiasmolithus consuetus* (Bramlette & Sullivan) Hay & Mohler, distal view. 7 200 ×; sample 11.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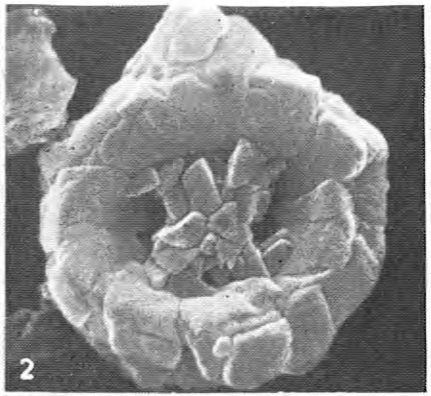
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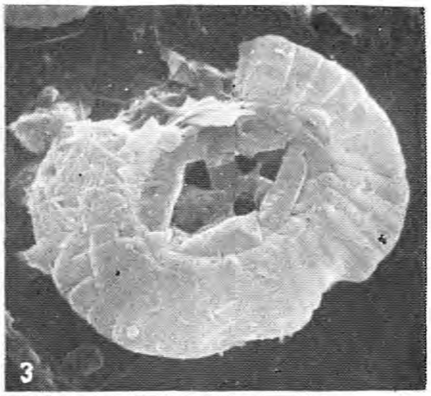
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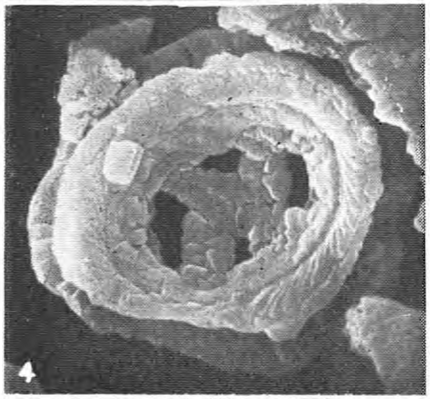
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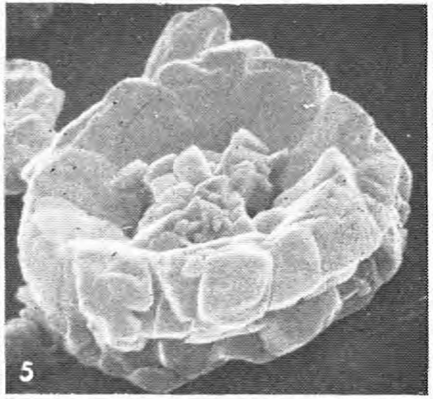
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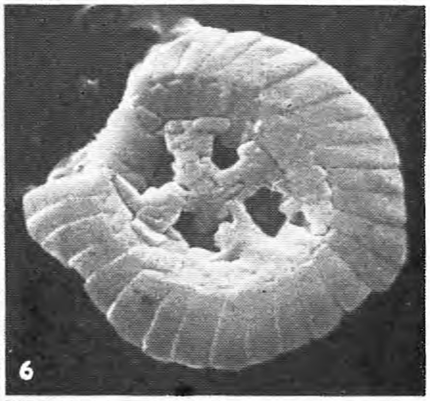
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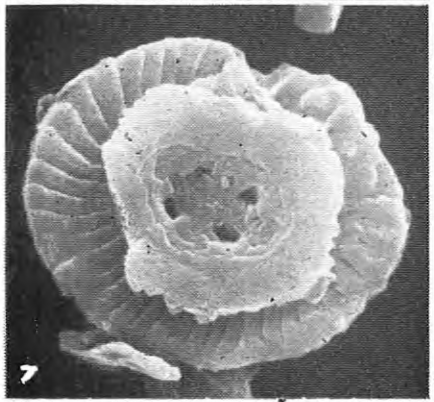
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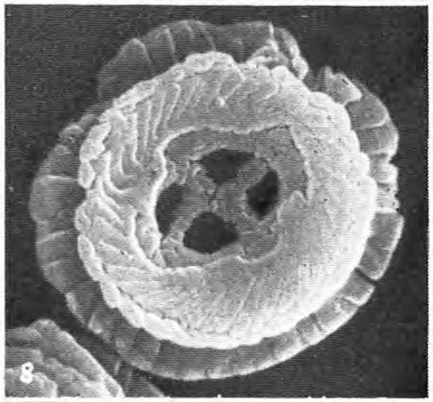
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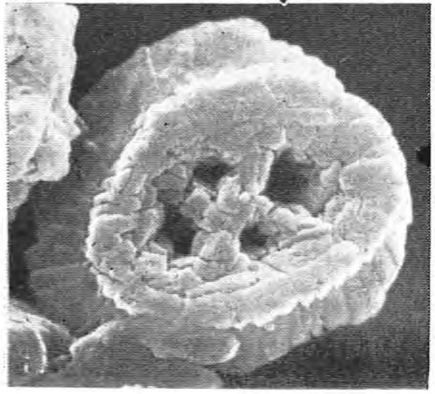

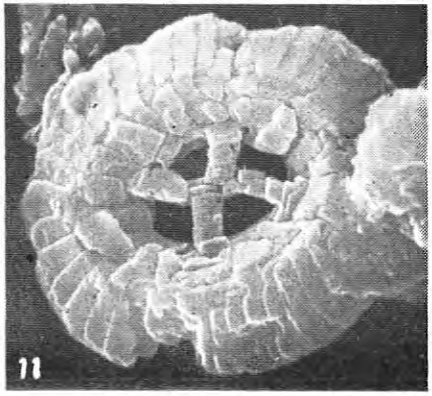
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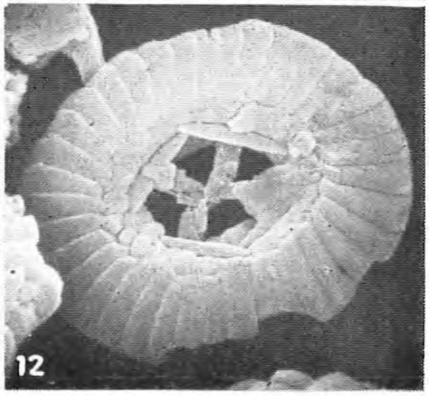
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PLATE 12

1. — *Ericsonia subpertusa* Hay & Mohler, distal view. 6 800 ×; sample 11.

2. — *Campylosphaera eodela* Bukry & Percival, distal view. 11 800 ×; sample 14.

3, 6, 9, 12. — *Cruciplacolithus notus* Perch-Nielsen, distal views. 5 300 ×, 5 100 ×, 5 600 ×, 5 100 ×; samples 13 (figs. 3, 6) and 11.

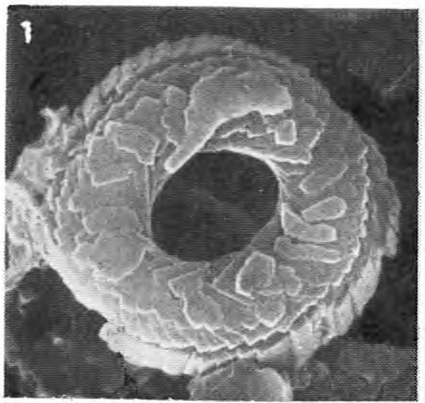
4. — *Cyclococcolithina robusta* (Bramlette & Sullivan) Gartner, proximal view. 5 600 ×; sample 11.

5. — *Campylosphaera dela* (Bramlette & Sullivan) Hay & Mohler, proximal view. 9 000 ×; sample 27.

7, 10. — *Ericsonia ovalis* Black, distal views of a heavily overgrown and a well preserved specimen. 7 200 ×, 5 600 ×; samples 11, 16.

8. — *Cruciplacolithus* ? sp. 11 000 ×; sample 11.

11. — *Cruciplacolithus notus* Perch-Nielsen, proximal view of a broken specimen. 11 100 ×; sample 11.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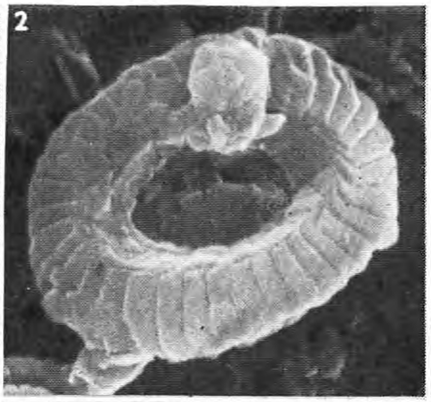
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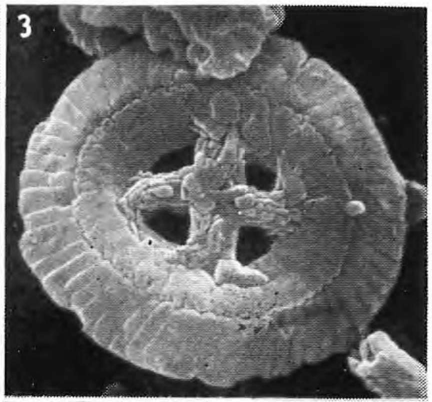
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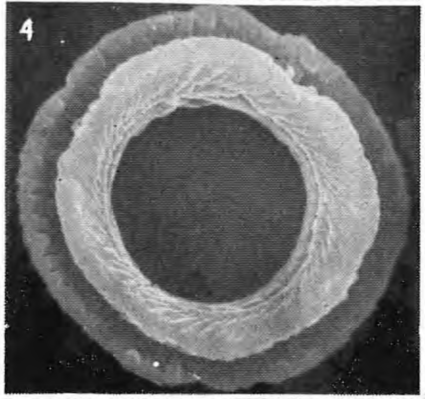
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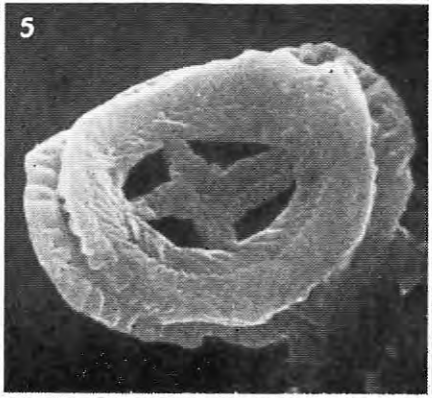
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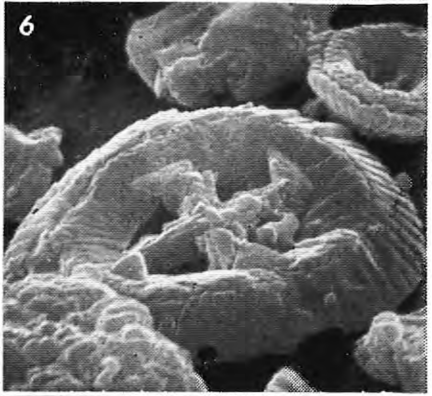
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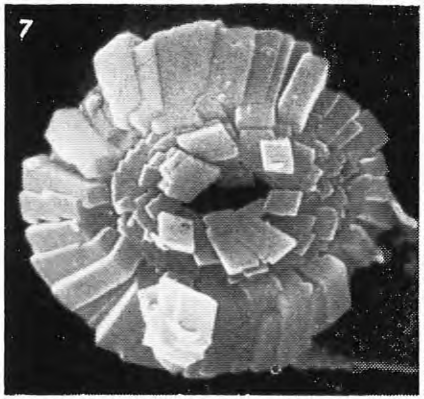
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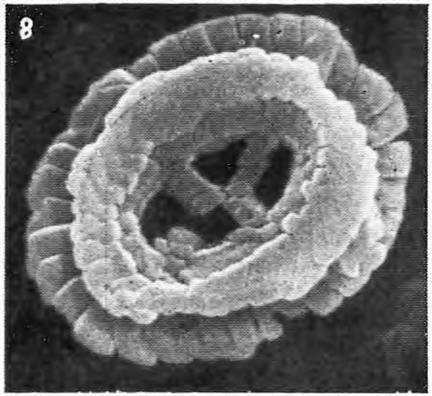
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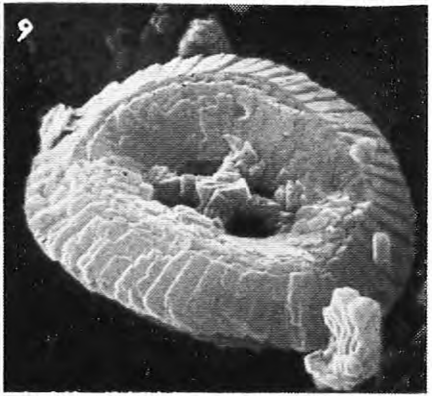
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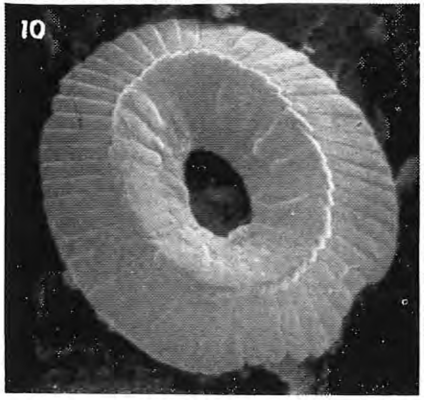
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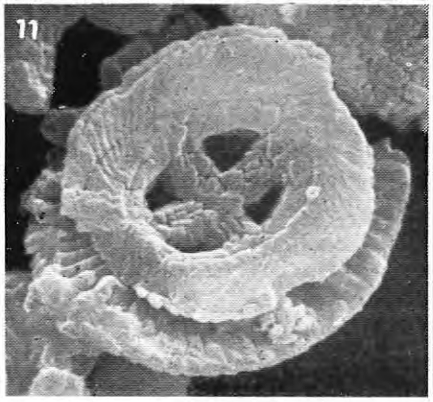
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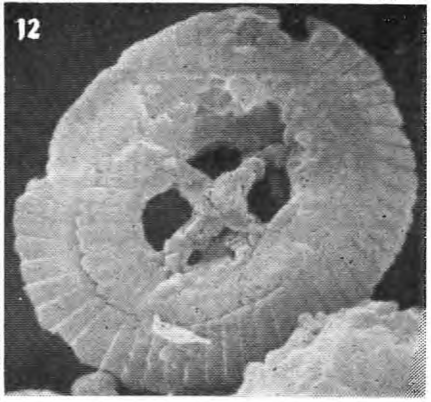
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PLATE 13

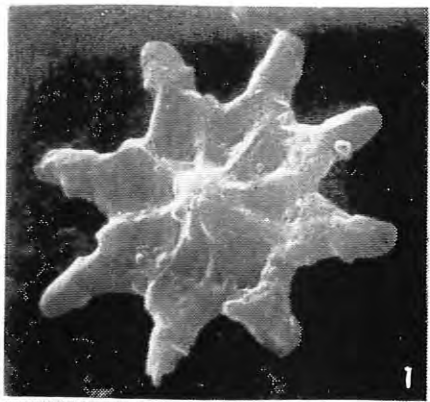
1, 4. — *Discoaster binodosus* Martini; specimens affected by solution (fig. 1) and overgrowth (fig. 4). 5 400 ×, 4 700 ×; samples 20, 21.

2, 3, 6. — *Discoaster diastypus* Bramlette & Sullivan; 3 400 ×, 3 200 ×, 3 100 ×; samples 21, 22 (fig. 6).

5, 7, 11. — *Discoaster multiradiatus* Bramlette & Riedel; 5 000 ×, 4 700 ×, 4 300 ×; samples 16, 20 (fig. 11).

8, 9. — *Discoaster salisburgensis* Stradner; 6 400 ×, 6 200 ×; samples 21, 22.

10 — *Discoasterides* cf. *D. megastypus* Bramlette & Sullivan; 4 700 ×; sample 22.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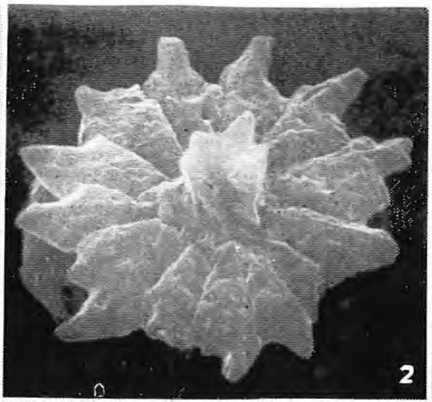
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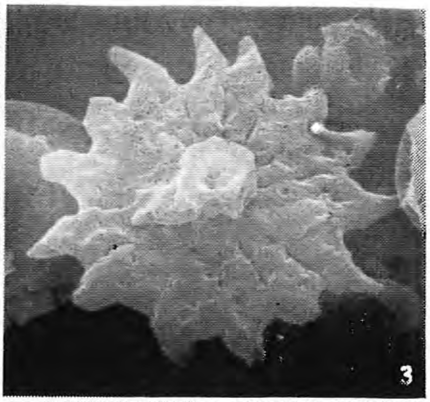
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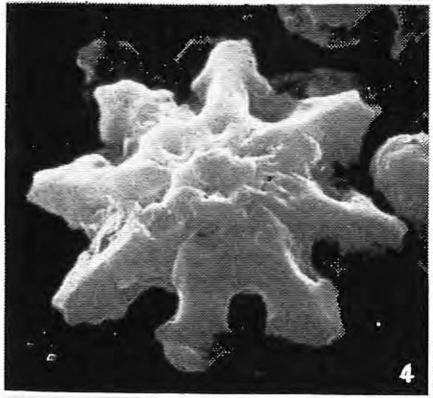
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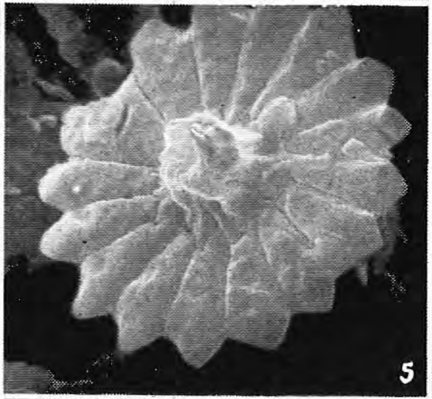
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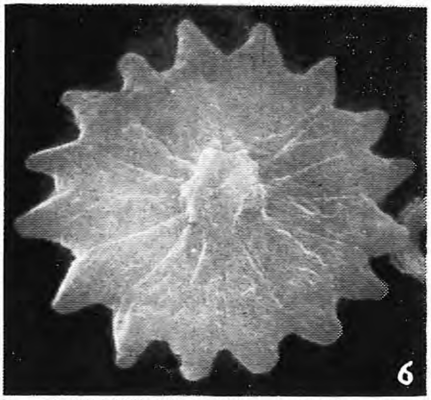
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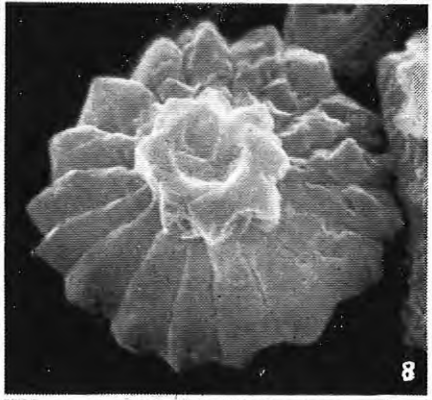
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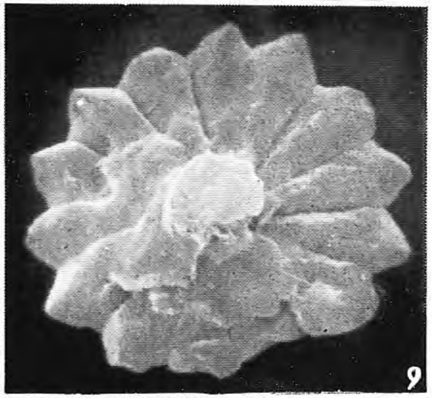
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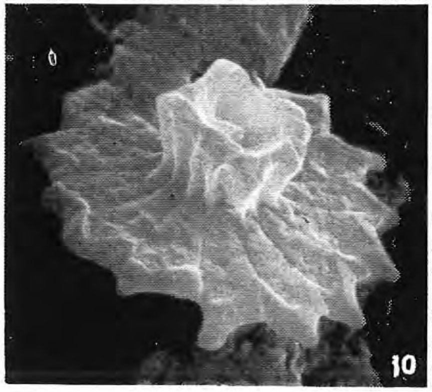
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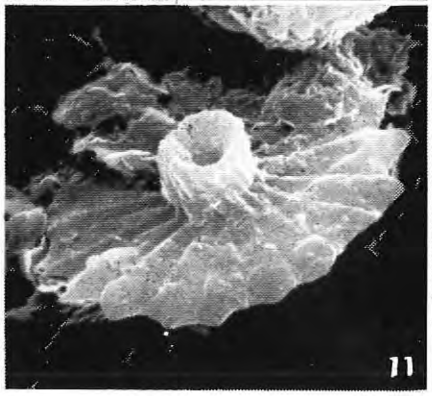
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PLATE 14

1\. — *Heliolithus* sp., proximal view. 9 000 ×; sample 13.

2-6. — *Markalius Variabilis* Perch-Nielsen 1977, 8 400 ×, 7 600 ×, 8 600 ×, 8 200 ×, 9 900 ×; sample 13.

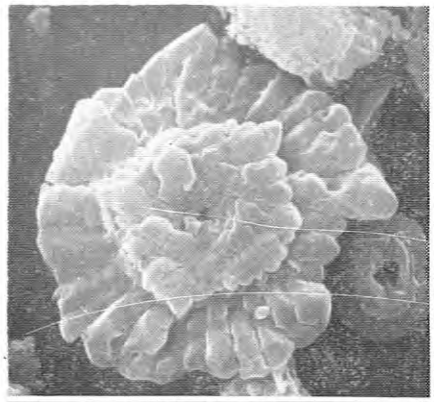
7, 10, 11. — *Discoaster binodosus* Martini, with heavily overgrown central knob 5 700 ×, 6 100 ×, 5 700 ×; sample 16.

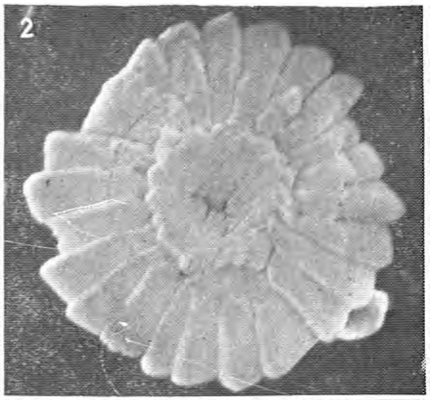
8\. — *Discoaster* ? sp. 11 800 ×; sample 14.

9\. — *Discoasteroides bramlettei* Bukry & Percival, 7 000 ×; sample 13.

12\. — *Discoaster multiradiatus* Bramlette & Riedel. 8 600 ×; sample 13.

PL. 14

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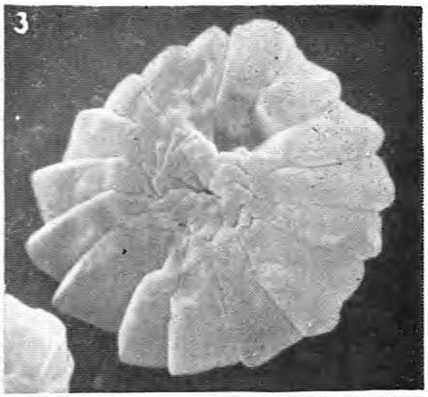
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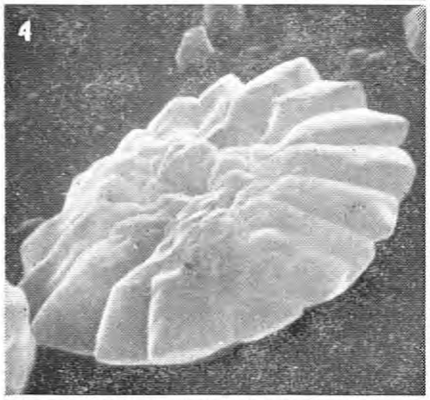
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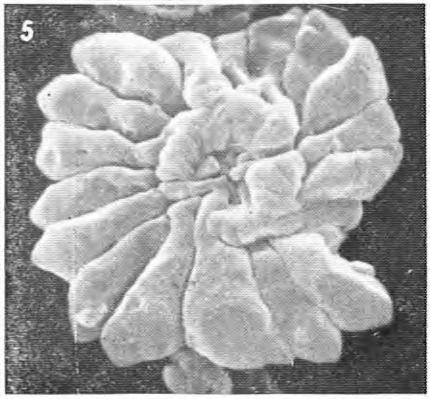
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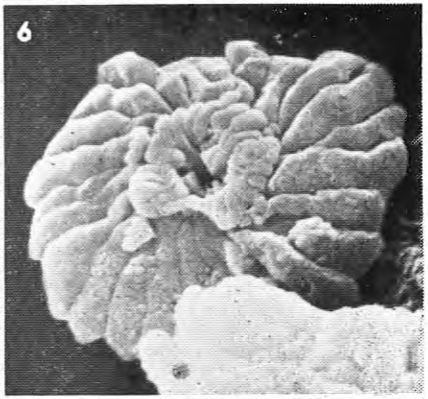
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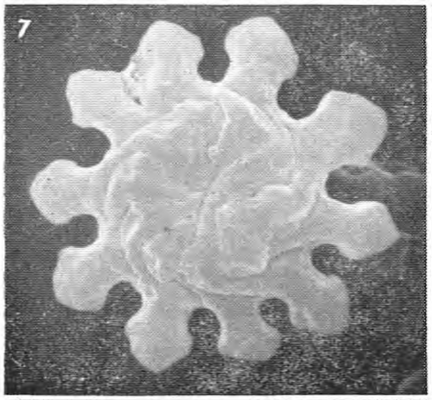
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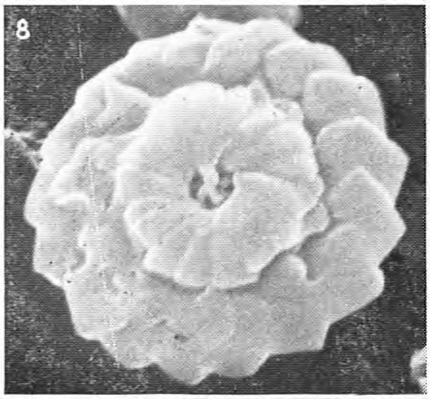
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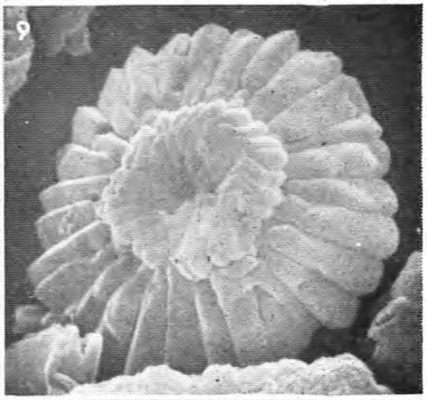
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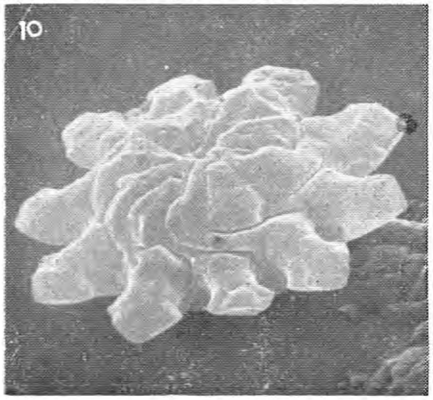
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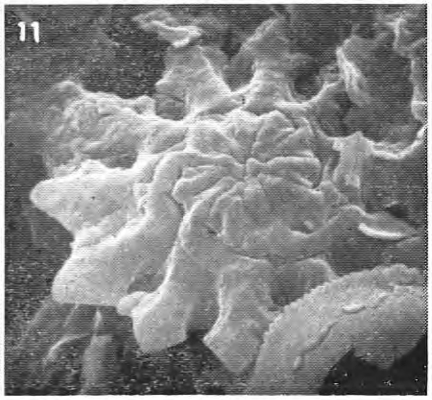
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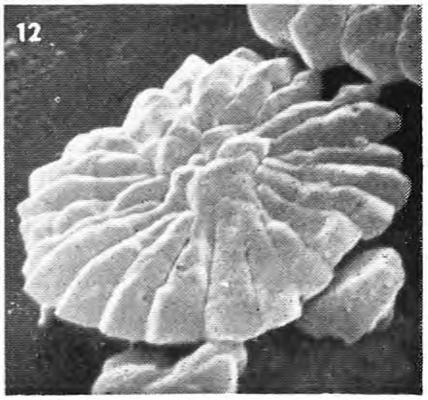
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PLATE 15

1, 3, 6. — *Heliolithus cantabriae* Perch-Nielsen, oblique views of incomplete specimens. 10 600 ×, 7 200 ×, 7 000 ×; sample 13.

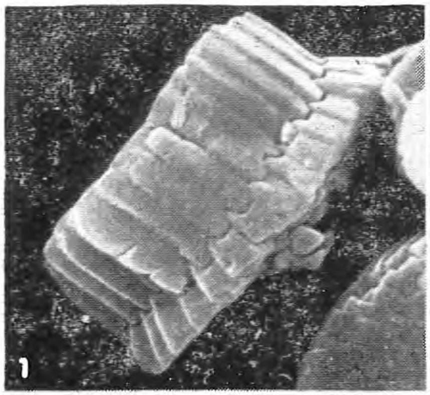
2, 5. — *Fasciculithus* cf. *F. janii* Perch-Nielsen, oblique proximal views. 7 400 ×, 10 100 ×; sample 13.

4. — *Heliolithus kleinpellii* Sullivan, oblique proximal view. 5 800 ×; sample 13.

7, 9, 12. — *Fasciculithus* sp., oblique proximal and side views. 4 400 ×; 4 500 ×, 4 900 ×; samples 13, 13, 11.

8. — *Fasciculithus ulii* Perch-Nielsen, side view. 9 100 ×; sample 13.

10, 11. — *Fasciculithus tympaniformis* Hay & Mohler, oblique distal and side view. 7 000 ×, 9 900 ×; sample 11.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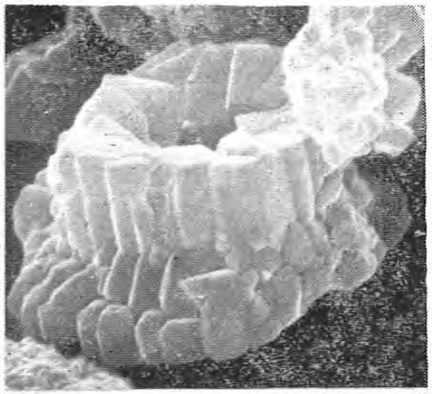

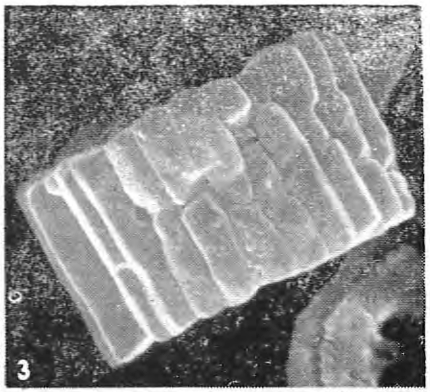
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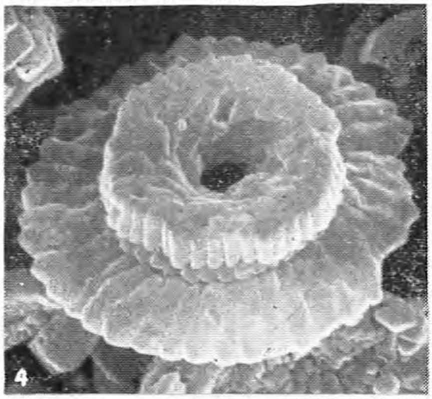
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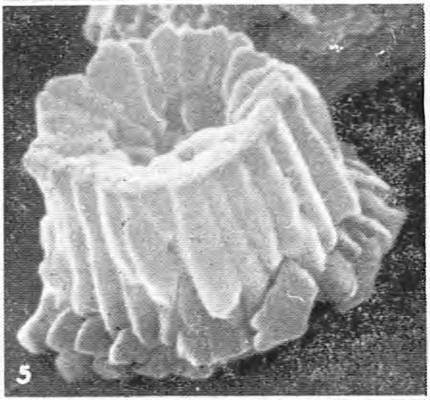
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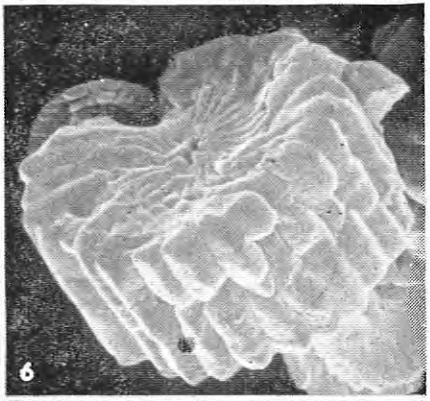
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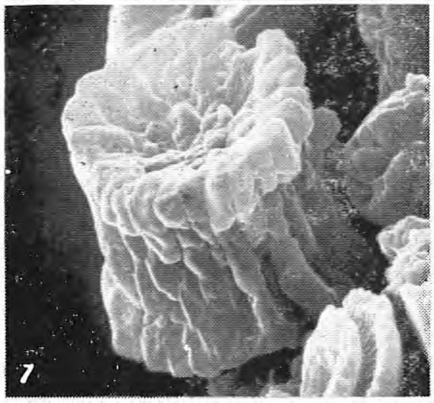
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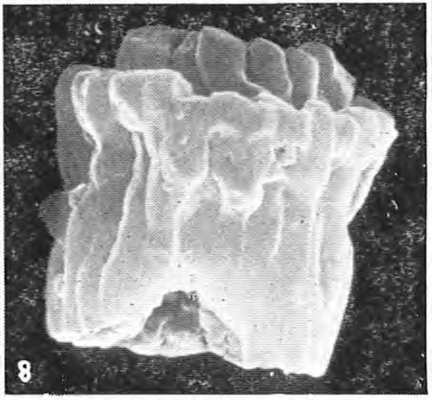
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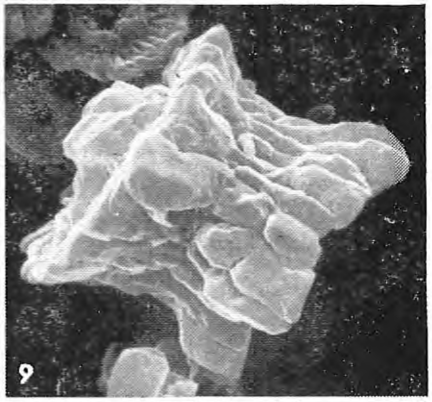
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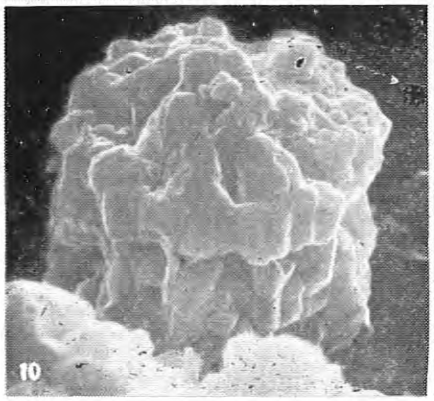
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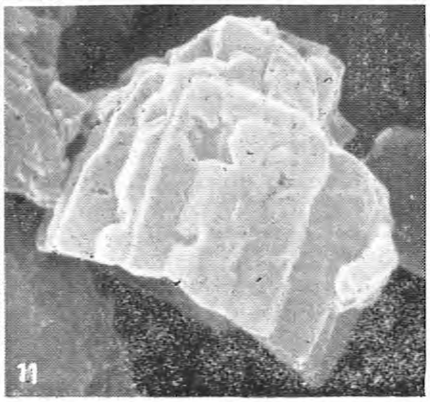
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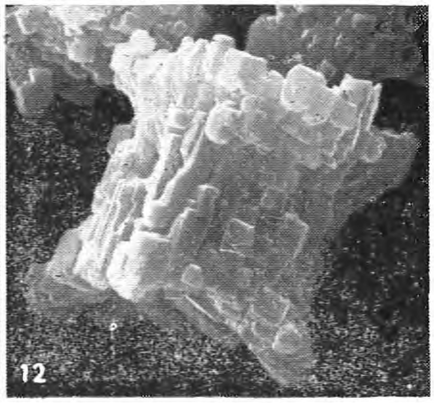
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PLATE 16

All specimens from sample 13, Late Paleocene

1, 5. — *Heliolithus kleinpellii* Sullivan, distal views. 6 500 ×, 6 000 ×.

2-4, 6, 9, 12. — *Heliolithus cantabriae* Perch-Nielsen, oblique and distal views. 8 800 ×, 4 600 ×, 8 400 ×, 4 800 ×, 7 200 ×, 7 100 ×.

7, 8, 11. — *Bomolithus elegans* Roth, oblique distal views. 7 200 ×, 8 600 ×, 8 600 ×.

10. — *Discoaster multiradiatus* Bramlette & Riedel, oblique distal view. 8 800 ×.

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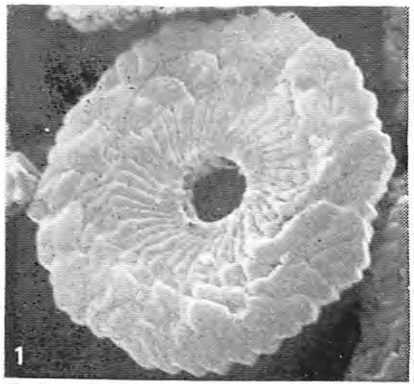
PL. 16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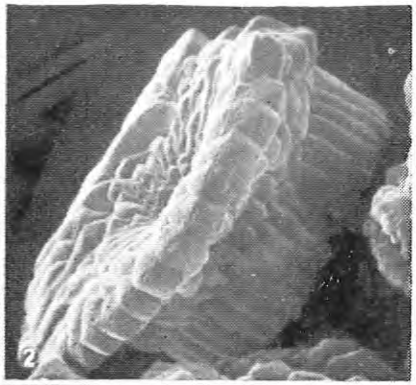
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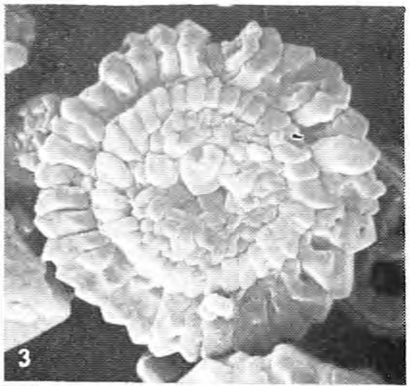
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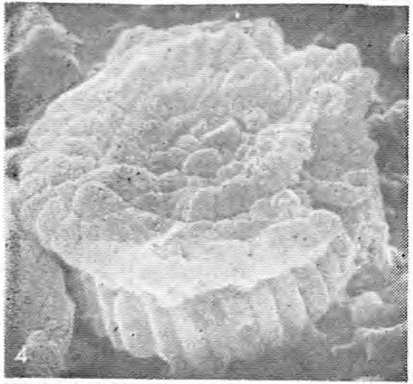
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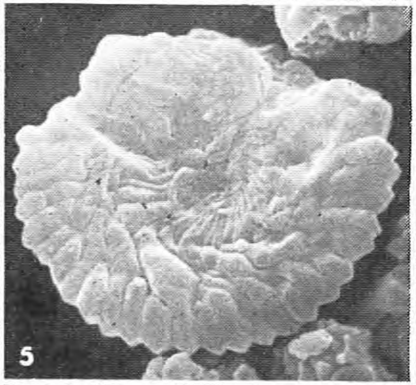
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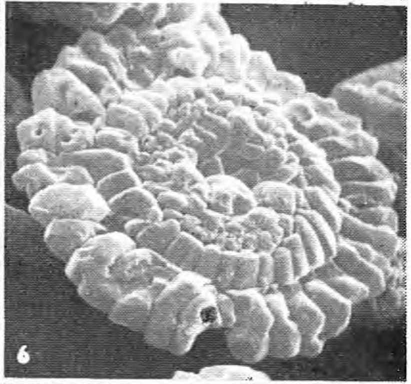
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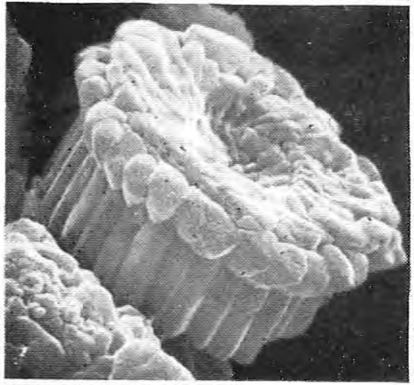
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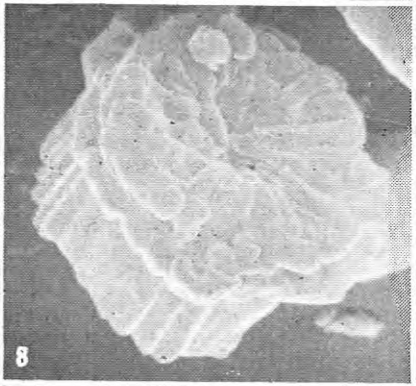
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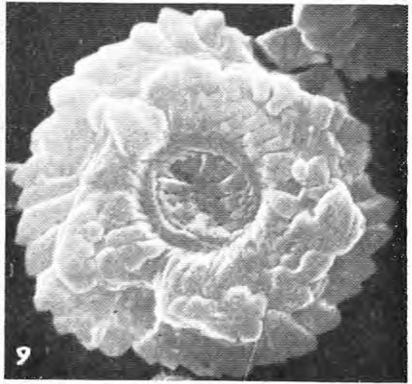
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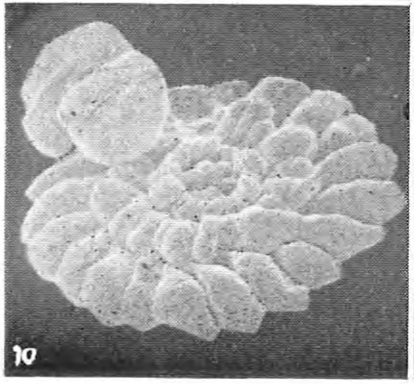
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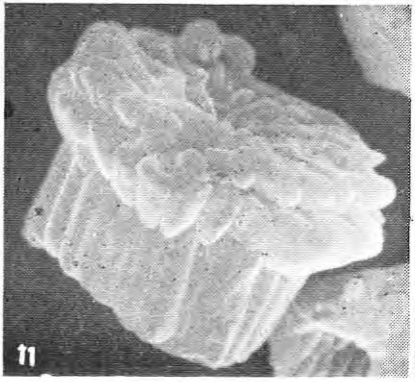
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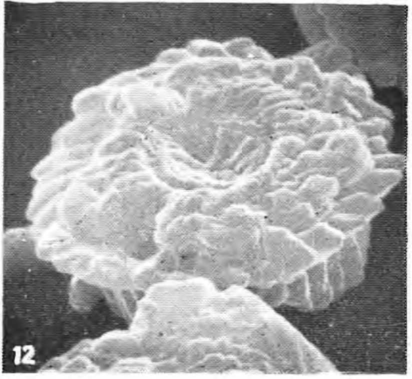
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PLATE 17

All specimens from sample 13, Late Paleocene

1, 4-7. — *Heliolithus kleinpellii* Sullivan, proximal views. 7 400 ×, 4 800 ×, 7 000 ×, 4 800 ×.

2, 3, 12. — *Heliolithus cantabriae* Perch-Nielsen, distal views. 6 200 ×, 5 500 ×, 7 500 ×.

8, 9, 11. — *Bomolithus elegans* Roth, distal and oblique distal views. 7 600 ×, 3 500 ×, 7 500 ×.

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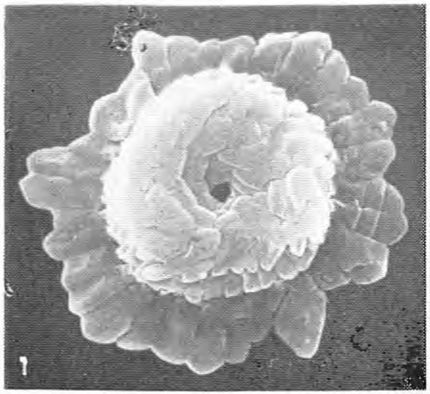
PL. 17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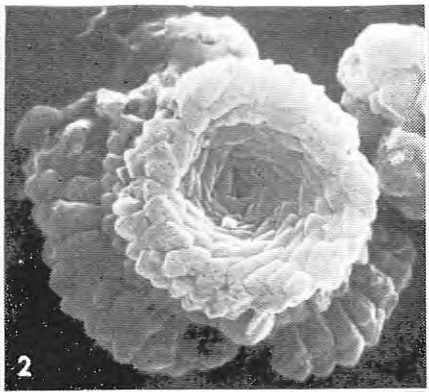
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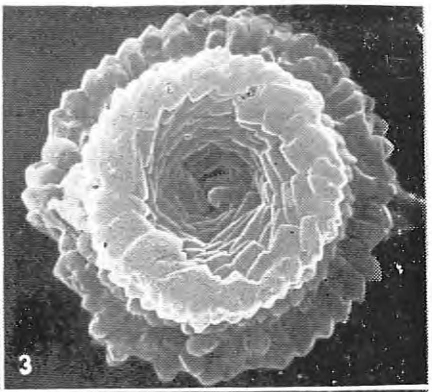
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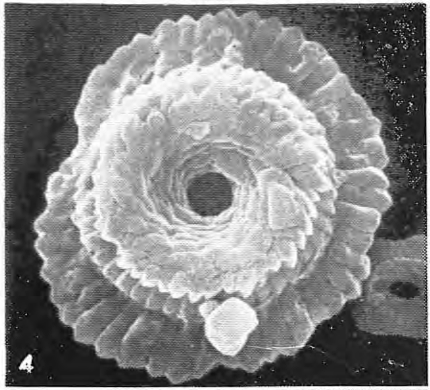
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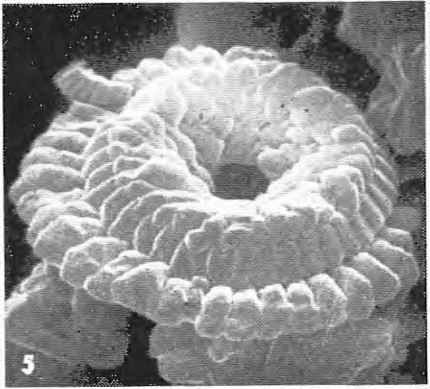
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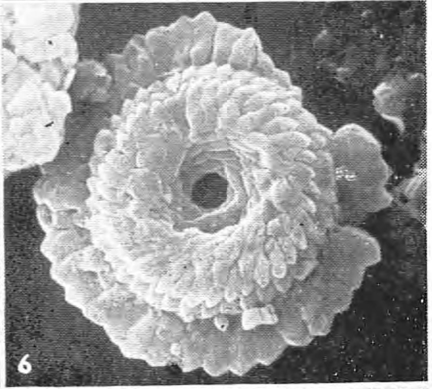
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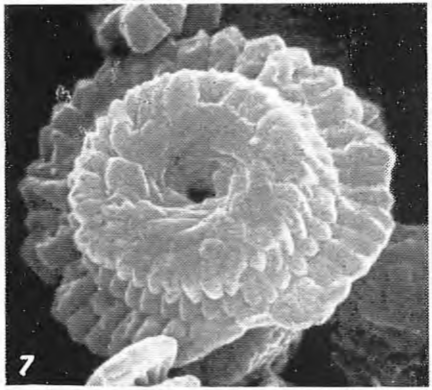
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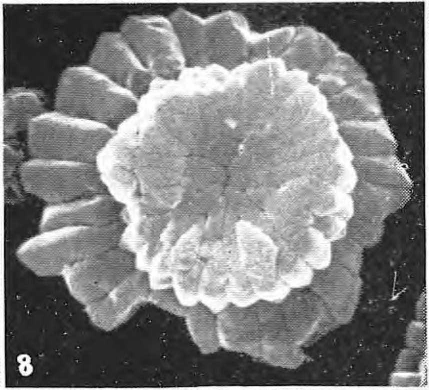
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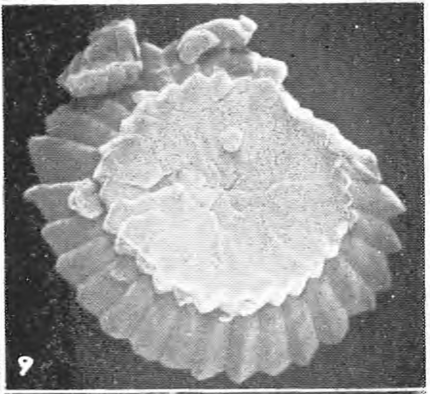
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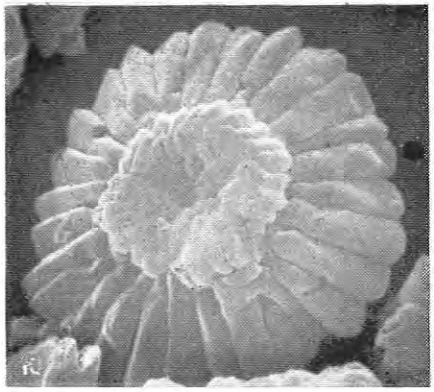
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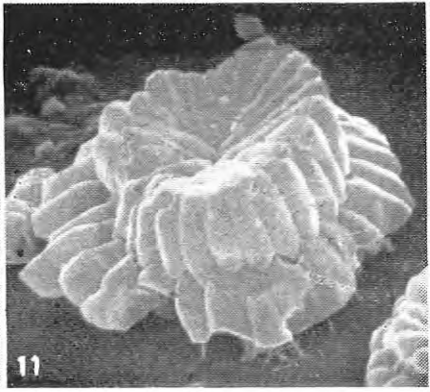
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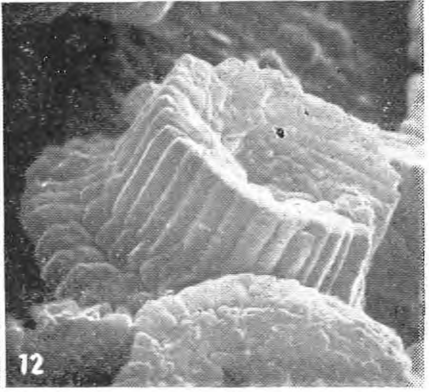
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PLATE 18

1, 9, 12, 13, 16, 17, 20. — *Toweius craticulus* s.l. Hay & Mohler, distal views (figs. 1, 12, 16, 20) and proximal views; statistical studies are necessary to subdivide this wide spanning species. 10 700 ×, 11 000 ×, 10 700 ×, 7 800 ×, 9 200 ×, 8 400 ×, 9 400 ×; samples 11 (fig. 13), 16 (figs. 9, 12), 20 (fig. 20), 21 (fig. 21) and 22 (figs. 16, 17).

2. — *Toweius ? sp.* 1, proximal view. 11 700 ×; sample 13.

3. — *Toweius occulatus* (Locker) Perch-Nielsen, distal view. 9 700 ×; sample 13.

4, 10. — *Prinsius martinii* (Perch-Nielsen) Haq, distal and proximal view. 7 800 ×, 7 800 ×; sample 13 and 11.

5, 8. — *Toweius callosus* Perch-Nielsen, distal views of specimens with central areas of different diameter. 9 400 ×, 8 600 ×; sample 16.

6, 7. — *Toweius eminens* (Bramlette & Sullivan) Perch-Nielsen, proximal and distal view. 9 200 ×, 7 400 ×; sample 13.

11. — *Toweius tovae* Perch-Nielsen, distal view. 7 100 ×; sample 11.

14, 15, 18, 19. — *Toweius rotundus* n.sp., proximal and distal views. 13 700 ×, 14 400 ×, 12 000 ×, 12 700 ×; samples 14, 20 (figs. 18, 19) and 22. Holotype : fig. 15

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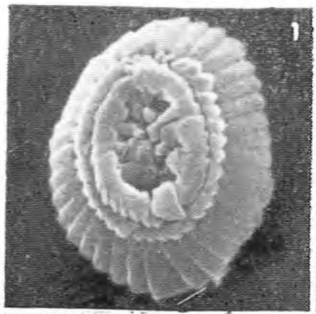
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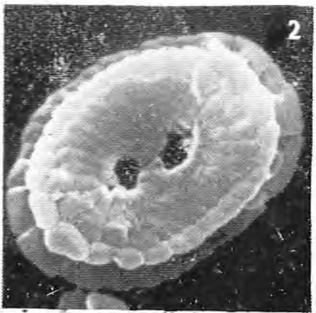
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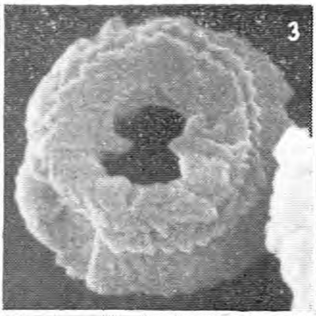
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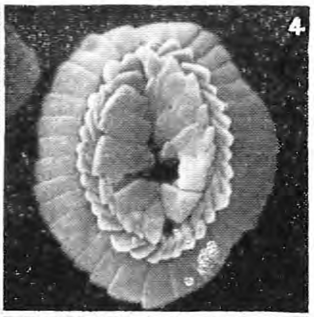
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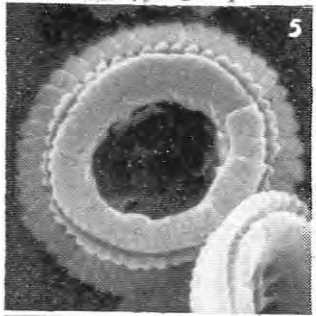
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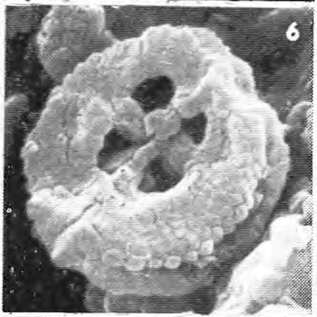
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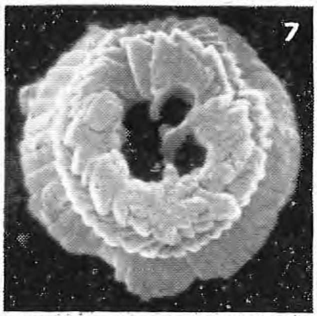
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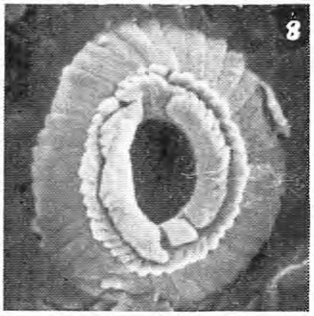
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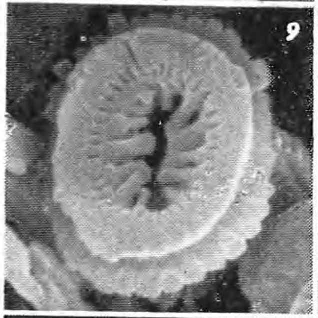
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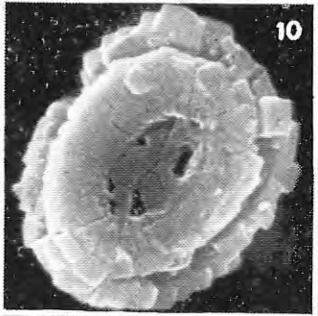
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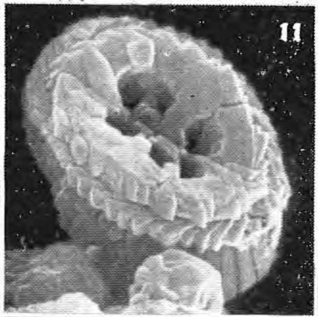
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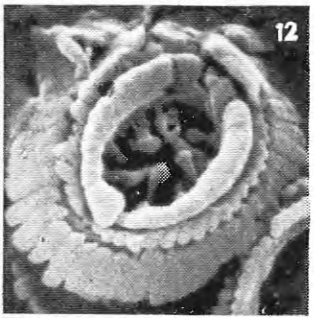
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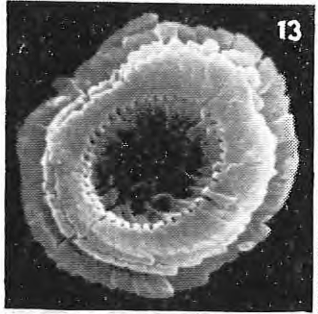
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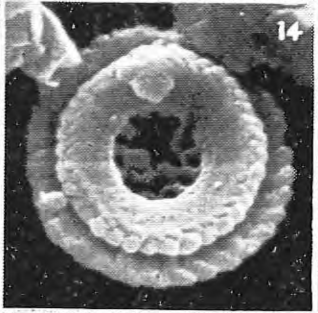
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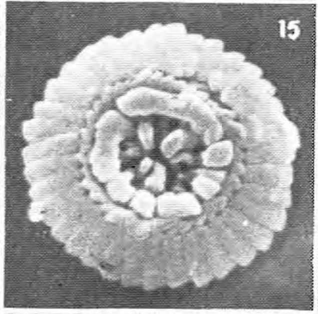
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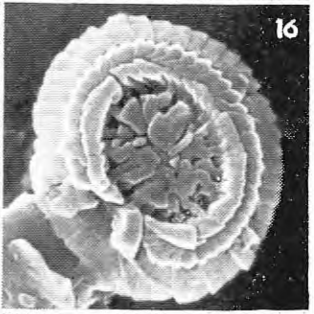
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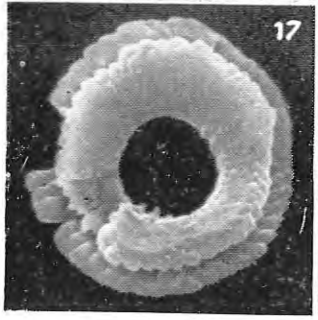
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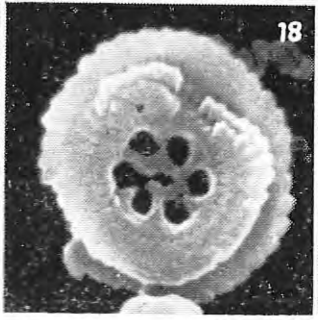
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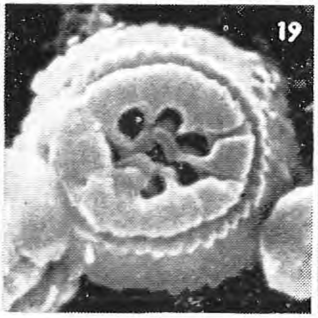
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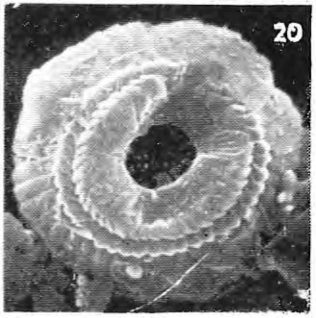
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PLATE 19

1-3. — *Zygodiscus sigmoides* Bramlette & Sullivan. sideview of a specimen with a central process, proximal and distal view. 7 000 ×, 7 600 ×, 7 400 ×; samples 11, 13 (fig. 3).

4. — *Zygodiscus plectopons* Bramlette & Sullivan, distal view. 7 500 ×; sample 13.

5. — *Zygodiscus adamas* Bramlette & Sullivan, distal view of a specimen with a broken transverse bar. 5 700 ×; sample 16.

6. — *Lophodolithus nascens* Bramlette & Sullivan, proximal view of a well preserved specimen. 4 900 ×; sample 21.

7, 10, 11. — *Pontosphaera rimosa* (Bramlette & Sullivan) n.comb. (*Discolithus rimosus* Bramlette & Sullivan, 1961, p. 143, pl. 3, figs. 12, 13), distal and oblique distal view and proximal view. 8 200 ×, 8 200 ×, 70 000 ×; sample 13.

8. — *Transversopontis* cf. *T. rectipons* (Haq) Roth, distal view. 7 800 ×; sample 22.

9. — *Transversopontis* cf. *T. exilis* (Bramlette & Sullivan) Perch-Nielsen, distal view. 6 200 ×; sample 16.

12. — *Pontosphaera versa* (Bramlette & Sullivan) n.comb. (*Discolithus versus* Bramlette & Sullivan, 1961, p. 144, pl. 3, fig. 16), distal view. 7 800 ×; sample 16.

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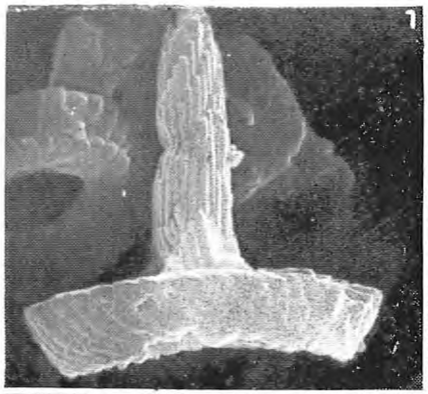

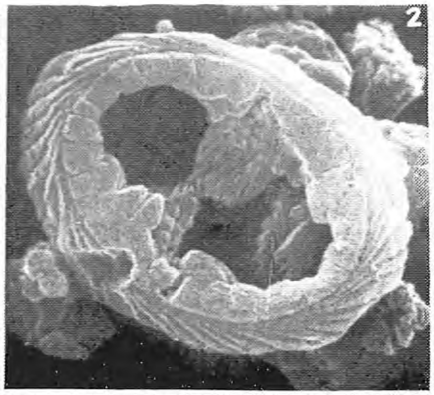

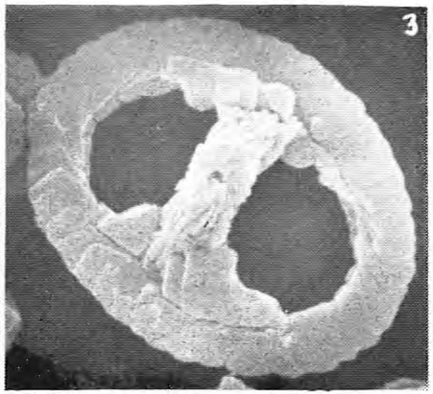

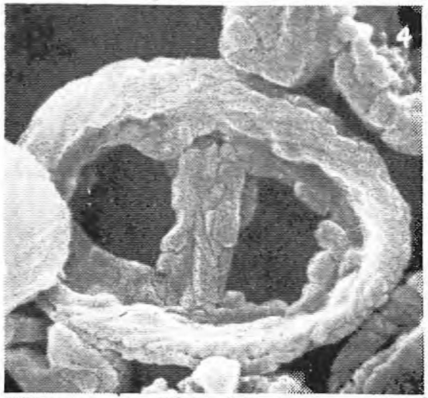

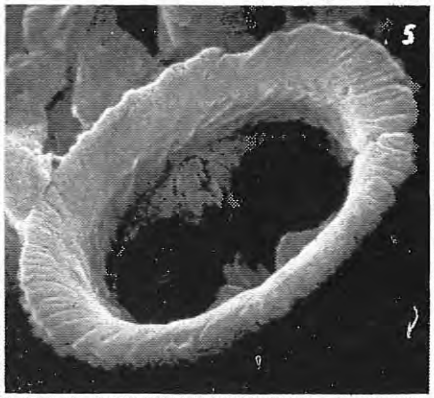

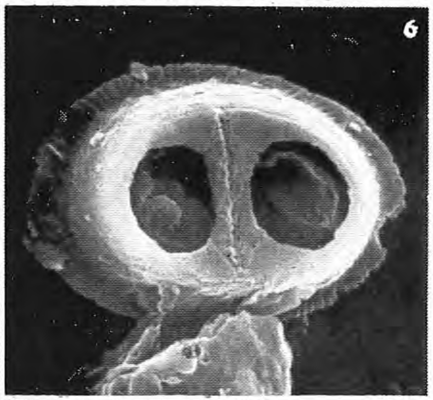

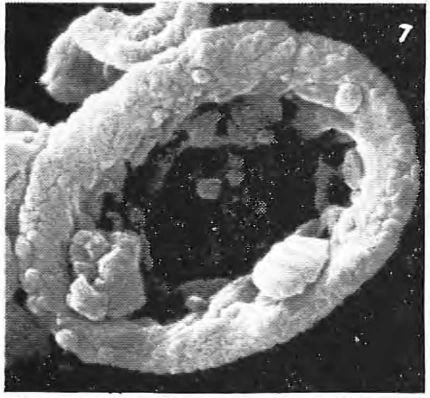

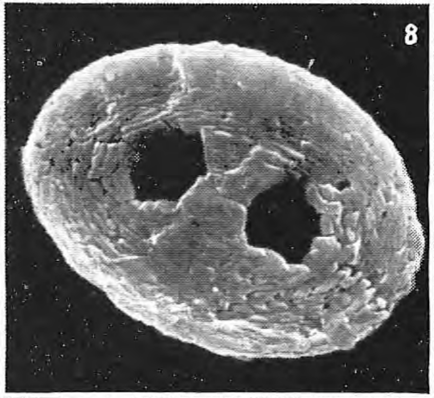

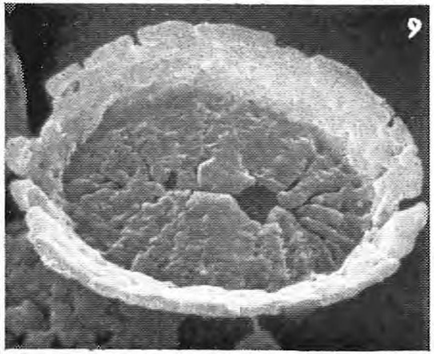

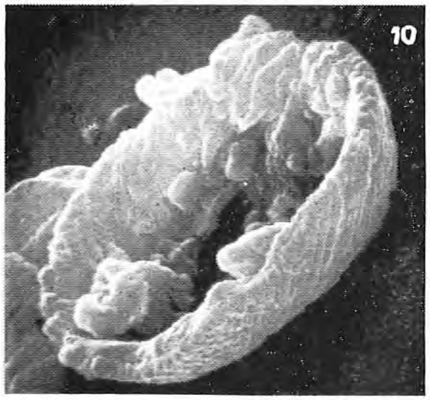

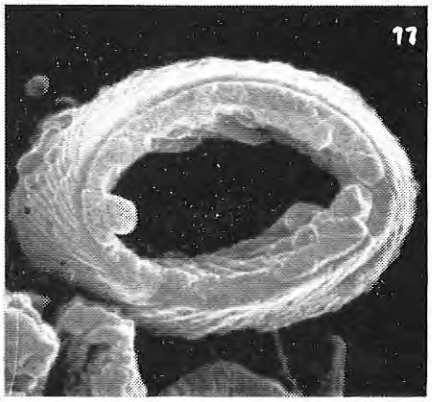

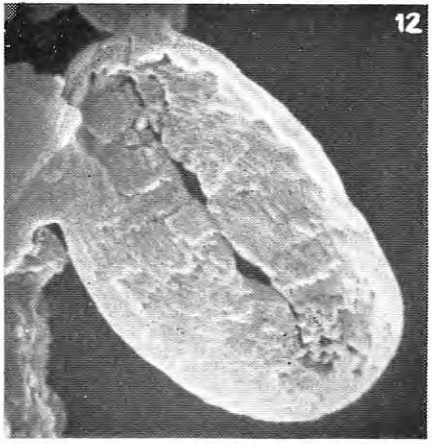

PLATE 20

1 — *Sphenolithus* cf. *anarrhopus* Bukry & Bramlette, oblique proximal view. 8 000 ×, sample 13.

2-4. — *Sphenolithus primus* Perch-Nielsen, side view and oblique proximal views. 14 500 ×, 7 800 ×, 8 600 ×; samples 16 (fig. 2) and 13.

5-19. — *Sphenolithus editus* n.sp., side views and oblique proximal views. 8 900 ×, 8 700 ×, 12 000 ×, 9 200 ×, 9 000 ×, 10 300 ×, 10 000 ×, 9 200 ×, 7 600 ×, 10 900 ×, 11 800 ×, 10 500 ×, 9 200 ×, 7 200 ×, 10 900 ×; samples 27 (fig. 17) and 22. Holotype : fig. 12.

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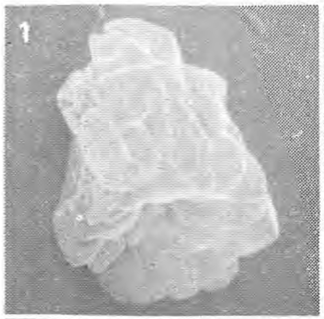
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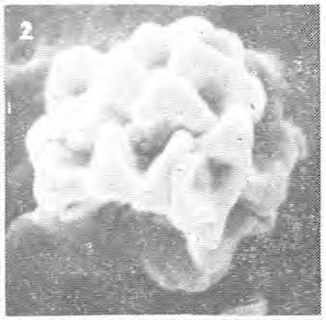
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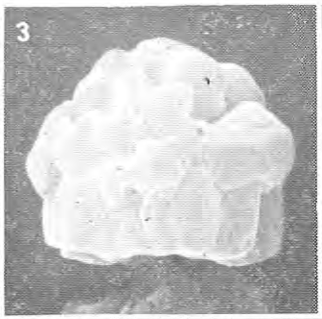
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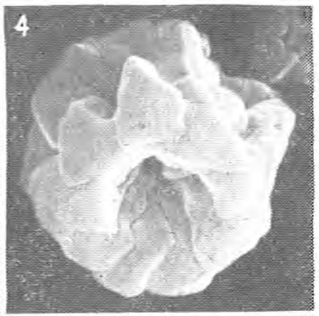
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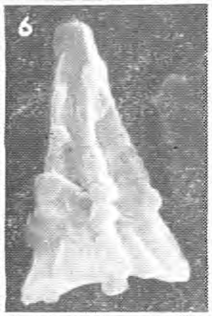
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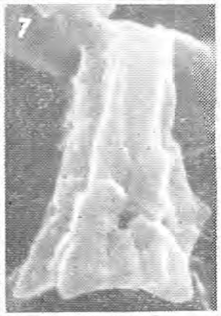
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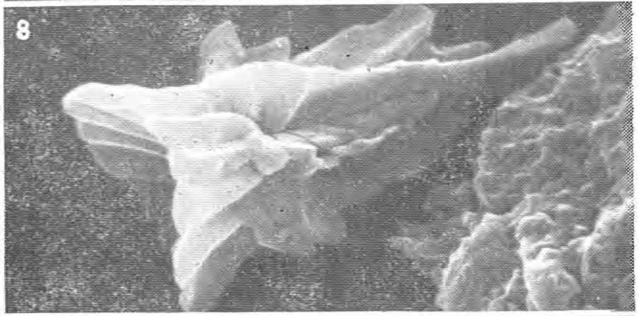
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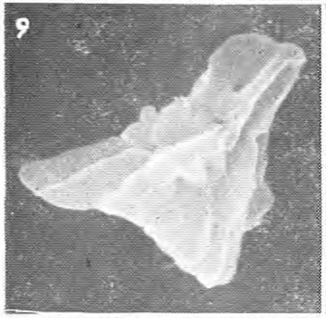
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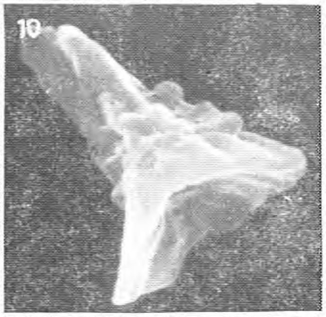
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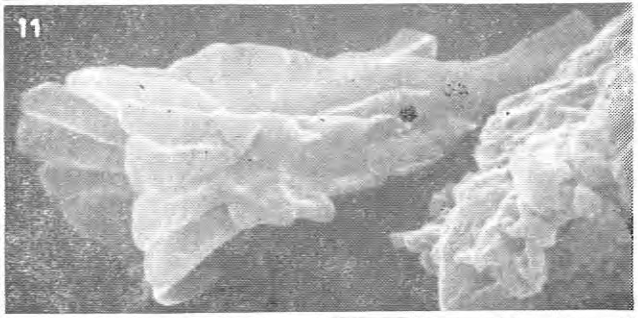
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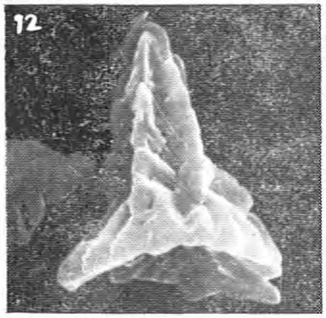
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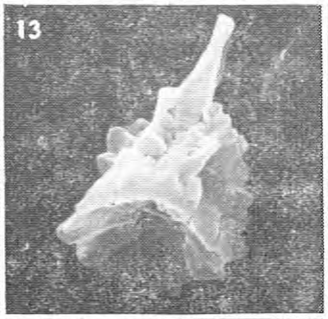
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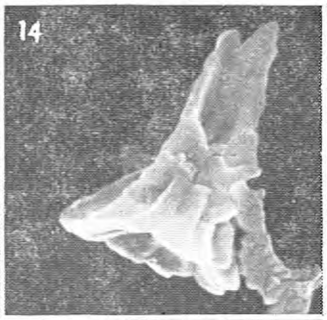
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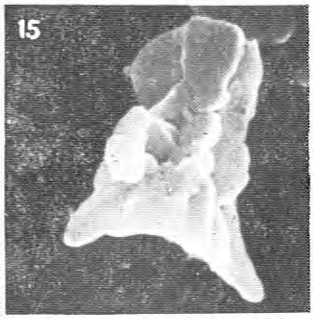
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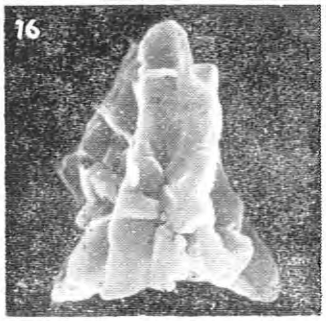
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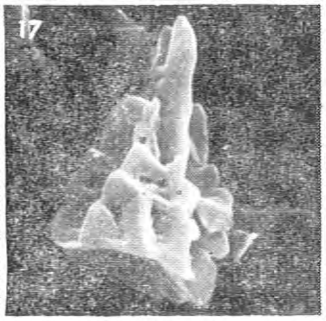
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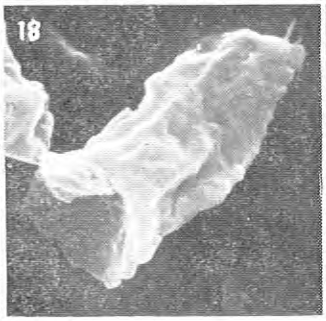
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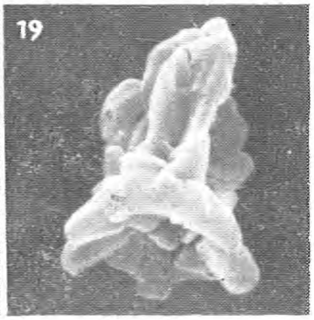
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PLATE 21

1, 2, 5, 6. — *Neochiastozygus* cf. *denticulatus* (Perch-Nielsen) Perch-Nielsen, proximal views (figs. 1, 6) and distal views. 14 500 ×, 13 800 ×, 10 100 ×, 11 800 ×; samples 27 (figs. 1, 2) and 13.

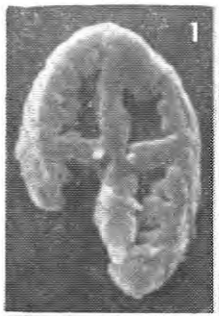
3. — *Neochiastozygus perfectus* Perch-Nielsen, distal view. 7 000 ×; sample 13.

4, 8, 11, 15-19. — *Neochiastozygus distentus* (Bramlette & Sullivan) Perch-Nielsen, proximal (figs. 8, 15) and distal views. 8 200 ×, 9 200 ×, 9 000 ×, 9 000 ×, 10 300 ×, 7 800 ×, 7 600 ×, 7 000 ×; samples 11 and 13.

7. — *Neochiastozygus saepes* Perch-Nielsen, proximal view. 11 300 ×; sample 13.

9, 10, 13, 14. — *Neococcolithes protenus* (Bramlette & Sullivan) Hay & Mohler, proximal (figs. 9, 13) and distal views. 10 700 ×, 10 100 ×, 8 400 ×, 8 600 ×; sample 11.

12. — *Neochiastozygus* sp.l, distal view. 9 000 ×; sample 11.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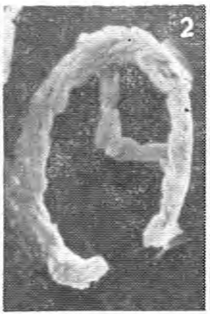
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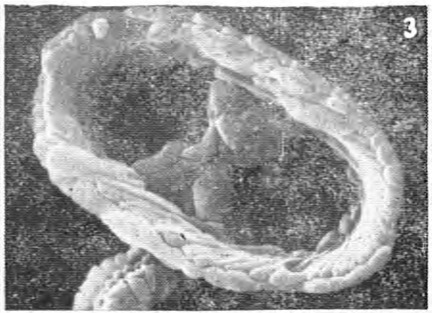
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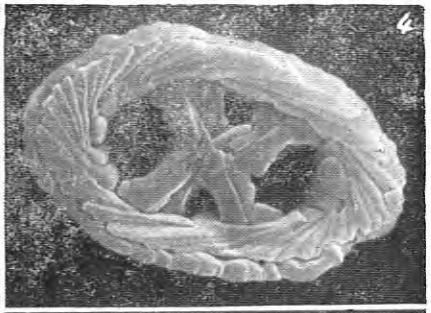
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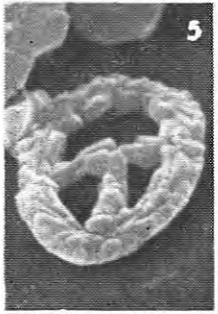
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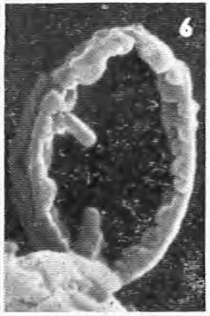
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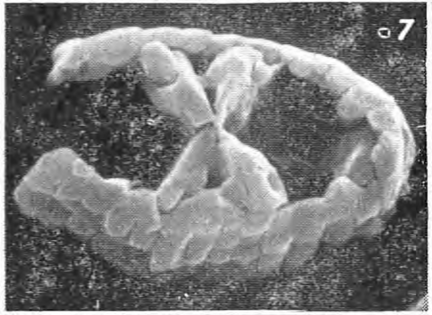
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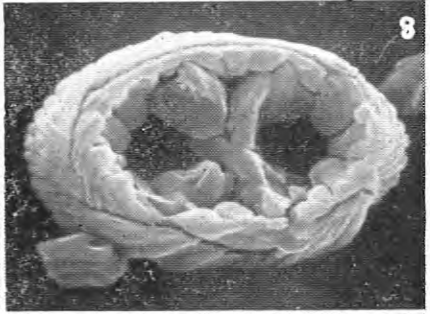
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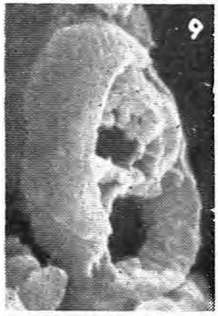
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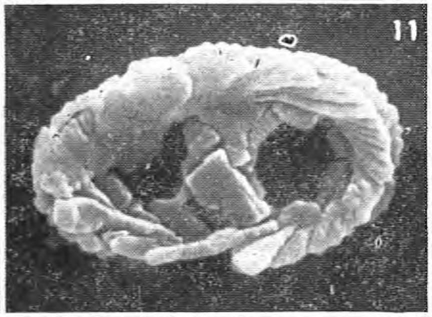
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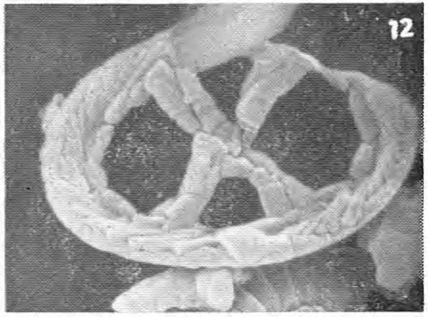
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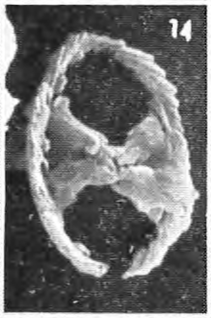
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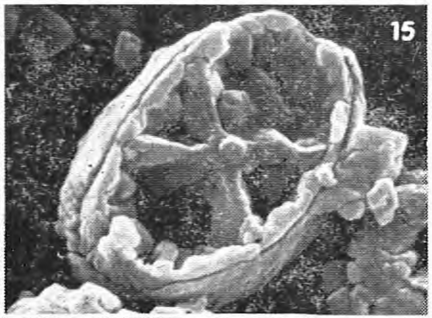
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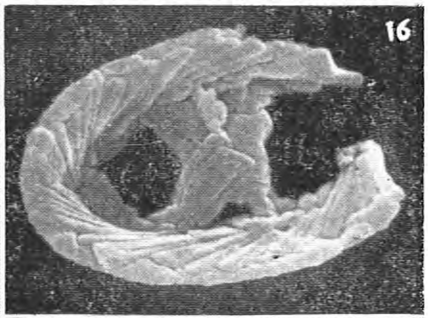
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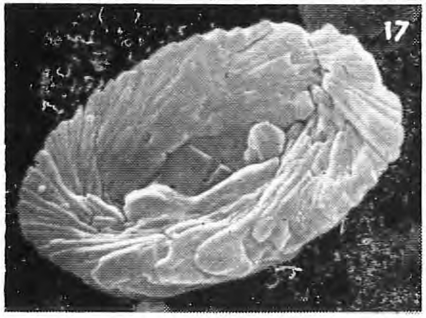
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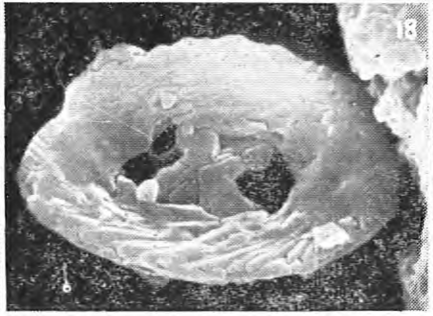
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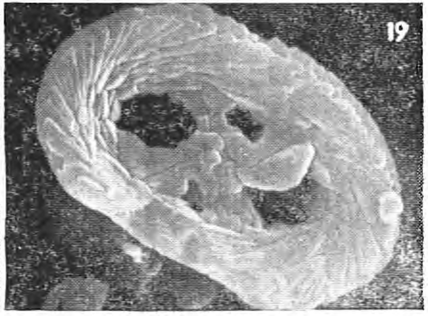
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PLATE 22

1, 4. — *Marthasterites tribrachiatus* Bramlette & Riedel. 4 800 ×, 7 400 ×; samples 22, 28.

2, 5. — *Marthasterites bramlettei* Brönnimann & Stradner, views of a turned specimen. 4 500 ×, 5 000 ×; sample 20.

3, 6. — *Marthasterites contortus* (Stradner) Deflandre, views of a turned specimen. 4 300 ×, 5 100 ×; sample 21.

7-9. — *Ellipsolithus distichus* (Bramlette & Sullivan) Sullivan, distal, proximal and oblique distal view. 8 400 ×, 9 200 ×, 7 600 ×; samples 11, 16, 13.

10-13. — *Ellipsolithus macellus* (Bramlette & Sullivan) Sullivan, oblique distal and side view, distal and proximal view. 5 800 ×, 5 700 ×, 5 700 ×, 4 900 ×; samples 20 (figs. 10, 11), 21 and 22.

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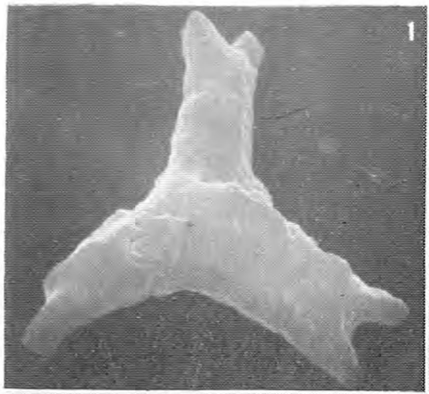
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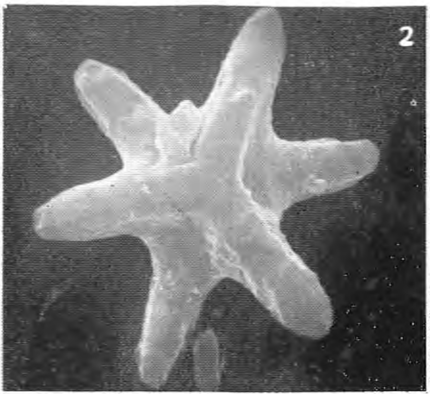
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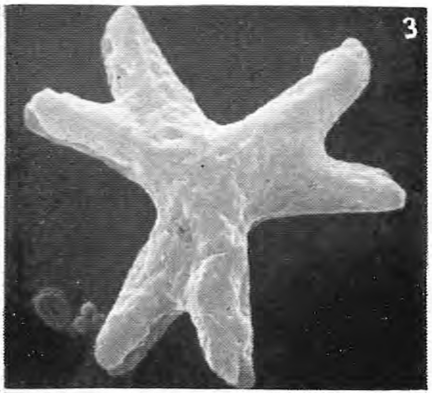
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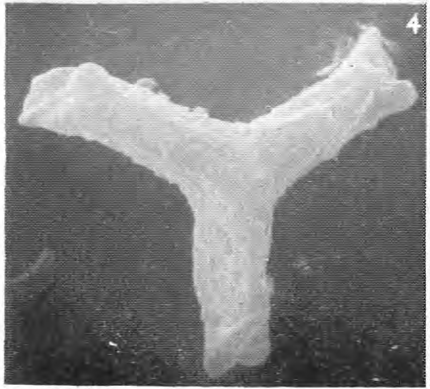
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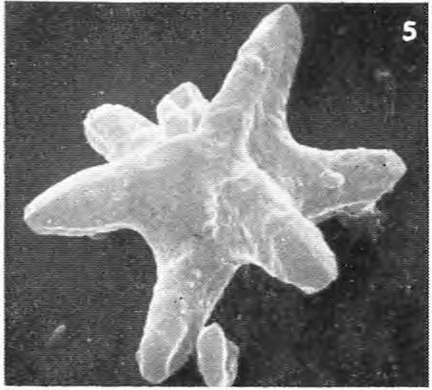
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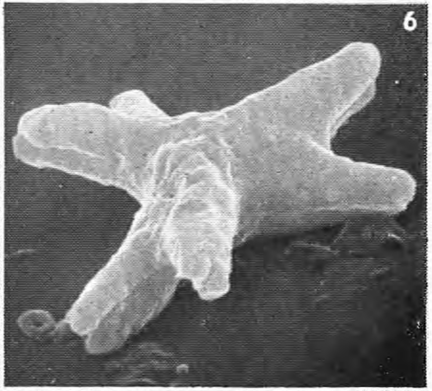
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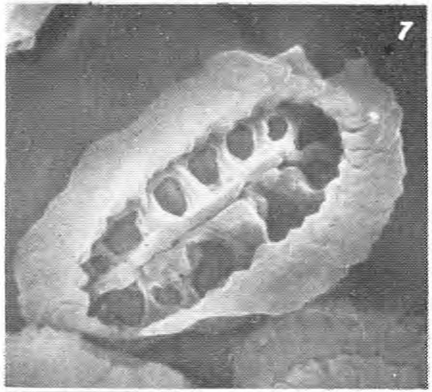
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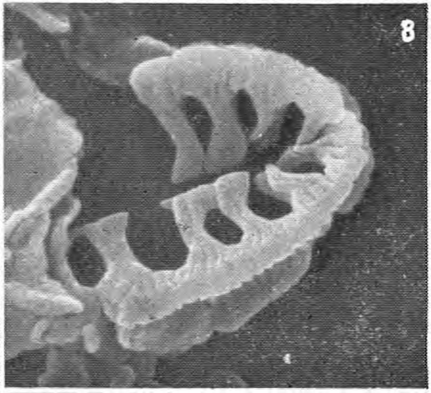
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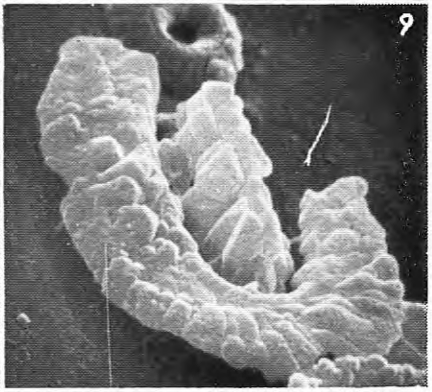
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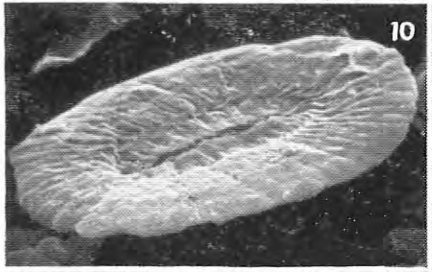
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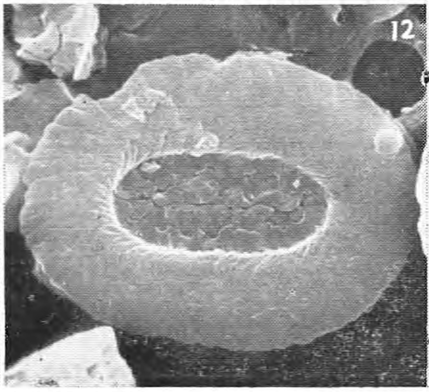
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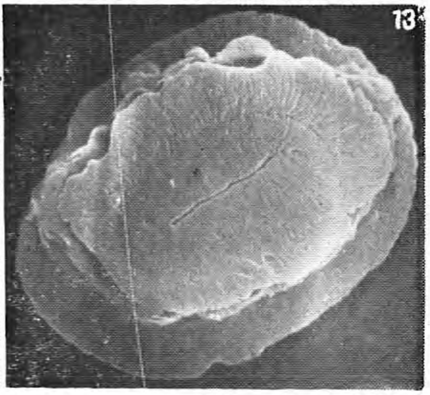
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PLATE 23

1-5, 7, 8. — *Semihololithus* cf. *S. kerabyi* Perch-Nielsen, specimens affected by overgrowth. 9 000 × (figs 1, 2), 9 900 ×, 8 600 ×, 7 500 ×, 8 100 ×; sample 22.

6. — *Semihololithus* ? sp., distal view. 10 700 ×; sample 22.

9, 10. — Gen et Sp. indet., views of a turned specimen. 9 700 ×, 9 900 ×, sample 20.

11. — *Scapholithus rhombiformis* Hay & Mohler, proximal view. 11 300 ×; sample 13.

12. — *Scapholithus fossilis* Deflandre, distal view (?). 8 600 ×; sample 20.

13. — *Polycladolithus* ? sp. 7 200 ×; sample 20.

14. — *Conococcolithus minutus* Hay & Mohler, distal view. 7 800 ×; sample 13.

15. — *Zygrhablithus bijugatus* (Deflandre) Deflandre. 8 800 ×; sample 27.

16. — *Micrantholithus aequalis* Sullivan, part of pentalith. 5 900 ×; sample 27.

17. — *Blackites spinosus* (Deflandre & Fert) Hay & Towe, distal view of shield. 9 900 ×; sample 20.

18. — *Rhabolithus solus* Perch-Nielsen. 10 300 ×; sample 21.

19. — *Thoracosphaera* sp. 3 400 ×; sample 13.

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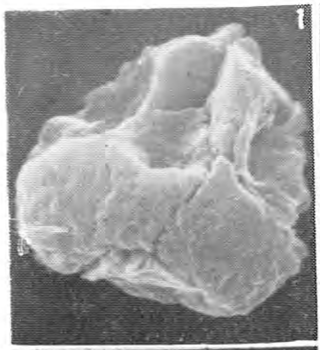
PL. 23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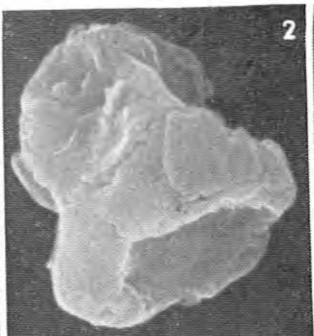
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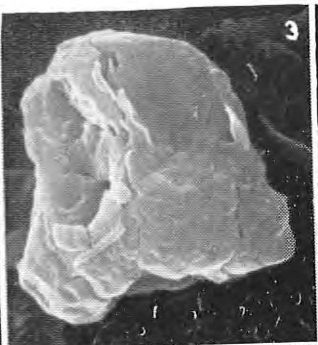
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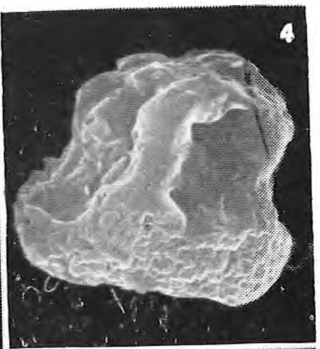
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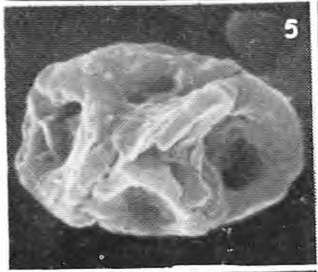
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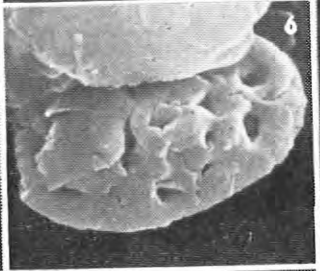
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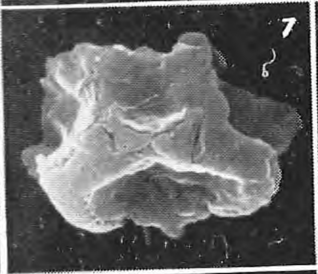
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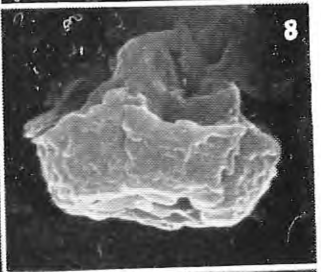
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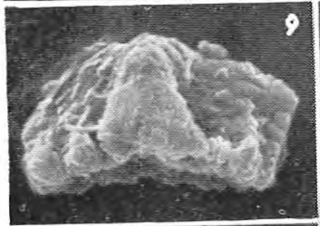
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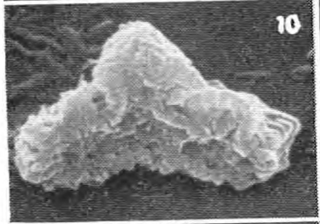
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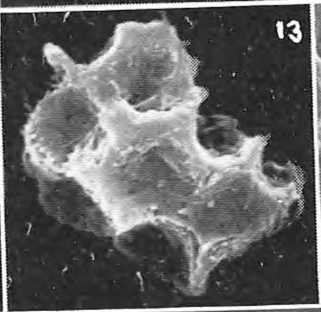
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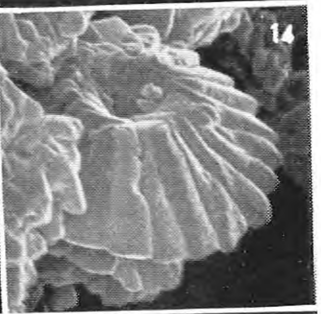
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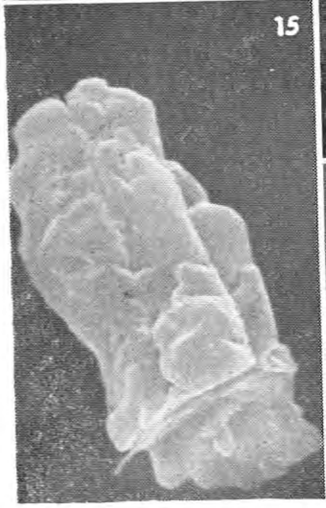
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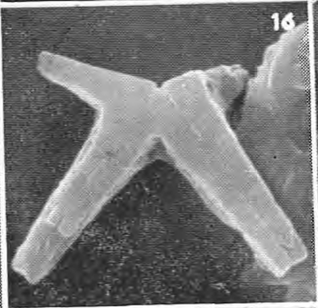
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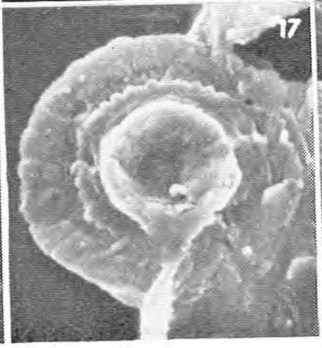
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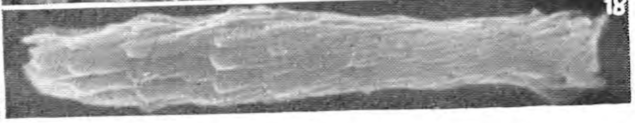
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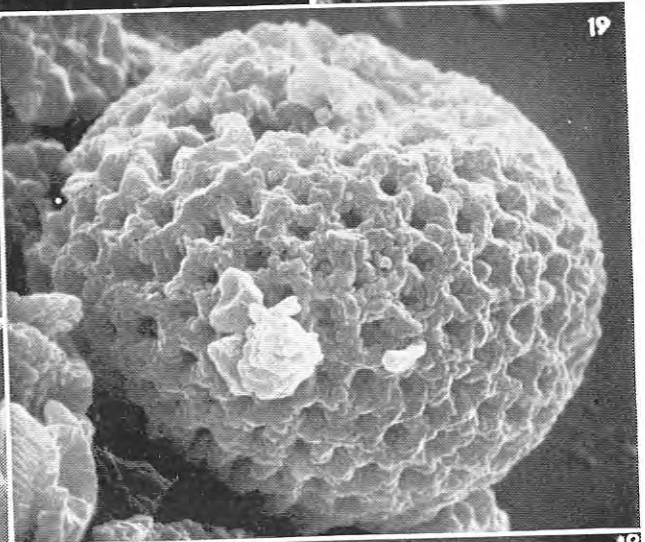
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